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Motto:

*,,**We cannot command Nature except by obeying her**.”*

Francis Bacon

TABLE OF CONTENTS

OVERVIEW OF ABBREVIATIONS

ADP - Adenosine diphosphate
ATP - Adenosine triphosphate
BCSD - Business Council for Sustainable Development
BJ - Mining Lake
BSK_5 - Biochemical Consumption of Oxygen (fivedaily)
CFC - Chlorofluorocarbon
CHSKcr - Chemical oxygen demand by dichromate method (K_2C)
$ChSK_{Mn}$ - Chemical oxygen demand of manganese
CP - City Part
CWEA - California Water Environment Association
DDT - Dichlorodiphenyltrichloroethene
DEE - Department of Environmental Engineering
EBRD - European Bank for Reconstruction and Development
EC - European Commission
EEB - European Environmental Bureau
EIT - European Institute of Innovation & Technology
EPA - European Pressphoto Agency
EU - European Union
EWEA - The European Wind Energy Association
FAO - Food and Agricultural Organization
FME - Faculty of Mechanical Engineering
ForWPL - Water Purification Lake
GEF - Global Environment Facility
GWEC - Global Wind Energy Council
GWP - Global Warming Potential
HS Orka - Iceland Renewable Energy Cluster
IAEA - International Atomic Energy Agency
ICBN - International Code of Botanical Nomenclature
IMO - International Maritime Organization
IPCEI - Important Projects of Common European Interest
IS - Insoluble Substances
ISWA - International Solid Waste Association
ITMS - Central Information System
IUCR - International Union for the Conservation of Resources
IWA - International Water Association
KenGen - The Kenya Electricity Generating Company Limited
KOH - Potassium hydroxide (solution with a concentration of 0,1 mol/l)
KTJ - Colonies Forming Units
LCA - Life Cycle Assessment
LTS - Summer Tourist Season

MoE SR - Ministery of Environment Slovak Republic
NADPH - Nicotinamide adenine dinucletide phosphate
ND - Not Detected
NEL - Non - polar Extractable Substances
NES - Non-Polar Extractable Substances
NGO - Nongovernmental Organization
NRC - National Research Council
NWT - Northwest Territory
OECD - Organisation for Economic Co-operation and Development
OPEC - Organisation of the Petroleum Exporting Countries
PCT - International Application (Patent Cooperation Treaty)
pH - Water acidity measurement parameter (Potential of Hydrogen)
PP - Particulate Pollutants
PPC - Polypropylene Compote
RÚVZ - Regional Public Health Offices
SAŽP - Slovak Environmental Agency
ŠF - Financial Management System of Structural Funds
ŠJ - Gravel Lake
SPS - Solid Polluting Substances
SR - Slovak Republic
SS - Soluble Substances
STN - Slovak Technical Standard
TOC - Total Organic Carbon
TUKE - Technical University of Košice
UN - United Nations
UNDP - UN Development Programme
UNECE - Economic Commission for Europe
UNEP - United Nations Environment Programme
UNESCO - United Nations Educational, Scientific and Cultural Organization
ÚPV SR - Property Office of the Slovak Republic
USA - United States of America
USD - American dollar
UV - Ultraviolet radiation
ÚVZ SR - Public Health Office of the Slovak Republic
VaV - Science and research
VN - Water Reservoir
WCED - World Commission for Environment and Development
WHO - World Health Organization
WMO - World Meteorological Organization
WTO - World Trade Organization

INTRODUCTION

The stabilized state of the natural environment, which existed millions of years before the first human ancestors appeared on the Earth, is now beginning to change to a slightly destabilized one.

The natural balance is disturbed by human activity. Man disposes of the most powerful and productive tool - his brain and an ability to think. This human ability is further enhanced by highly effective mutual communication between the people. In this way, the fruits of the mental work of a person, as an individual, spread faster and are also realized faster. Unlike other animals and plants, man does not draw from his environment only as much as he necessarily needs for his life, but has created high demands and demands for himself, which he calls the standard of living.

We have neglected in recent decades, our faith in the general power of the mind technology, which can protect a life from any problem, still persists in us, even if it receives great cracks during major natural and anthropogenic disasters. Humanity often uses natural resources disproportionately with its thoughtless activities, irreversibly contaminates the environment, sometimes not only from our point of view, but also from the point of view of future generations.

Humanity also uses natural resources to a large extent to build works that serve several generations and enable the use of alternative and renewable energy sources to an increasing extent (for example, the construction of hydro and wind power plants). The question is whether humanity currently uses and will use the earth's energy and raw material potential in the future to build sufficient environmentally suitable energy resources for the life of future generations. By this, we mean a process that includes not only the transition from energy production from fossil sources to renewable sources, but also the transition to less energy-intensive technologies and to products that require less energy for their operation. The problem from the point of view of the future is not the lack of energy, but the fact that with the growth of energy production, not only production but also environmental pollution increases.

The external environment represents the interactions of three natural spheres, namely the atmosphere, hydrosphere and pedosphere, as well as the mutual connection with the biosphere. The authors of the monograph focus their attention precisely on this area. They present the results of their long-term scientific and research activities in these areas.

The worldwide problem of surface water pollution is eutrophication, which means the excessive growth of plants and algae in waters with a high content of nutrients, especially nitrogen and phosphorus. In this area, original technical solutions designed by the authors of the monograph are presented, which are protected by domestic and foreign patents granted in the USA, Canada and Japan.

For several years, the authors' workplace has focused on the research, prediction and prevention of the spread of the emissions and the immissions of noise, vibrations, non-ionizing radiation, lighting and solid aerosols in the working and living environment. An attention is also focused on the development of methodologies, techniques and technical solutions for

minimizing these emissions and immissions. Selected results of scientific research in this area are presented in the monograph.
Also interesting are the results of scientific research aimed at the research of heavy metals present in the soils. The results are confronted with the research carried out about 10 years ago in an identical location. The presence of heavy metals represents a serious environmental burden.

The attention of the authors of the monograph is focused on the research of the impact of mechanical engineering production on the environment. The results of the scientific research work are presented and focused on "Environmental and Economic Factors and Their Expressions" and "Environmental Evaluation of Mechanical Engineering Products in Their Conceptual Phase".

The protection of the environment and the direction towards the development of society, which will enable economic development, increase the standard of living and at the same time preserve nature and resources for future generations, require knowledge of the current state. The result would be a qualitatively and environmentally more acceptable approach to the use of resources, production and consumption, which would not arise on the basis of orders or prohibitions, but on the basis of natural human knowledge, which can be further developed without the threat of sanctions or regulations.

The monograph can be an inspiration for researchers in their subject area of research. At the same time, it can help the new generation orientate in the areas of environmental protection.

Košice, November 2022 *Authors*

1 HUMAN POPULATION AND ENVIRONMENT

The whole human development has been very dependent on the environment in which it was located. Initially, the man lived only where had on his existence material protected for existence conditions (earth, air, plants, etc.). To change these conditions, he responded as follows [1]:

- adapt passively - dying,
- adapt actively - he interfered into environment through his activities and thereby created a new material (existential) conditions (e.g. agricultural soil/ land cultivation).

1.1 Man and Environment

The man was aware the dependence on the natural environment, he observed some relationships and the obtained experience he passed on from generation to generation. The aim was to preserve human society. Thus arose the first cultural and religious rules, which actually served as a precautionary steps to preserve life. [2]

A fundamental change occurred early with the production of working tools. The man started to influence on the nature. The degree of exposure of man on the nature was in proportion to his work activity. [1]

The man is a social creature and is never lonely. His life is always associated with the lives of other people - with the life of the companies. The interrelationship between human beings are determined by the social environment. Social environment is unique (specific) only to humans. It is a very dynamic environment, which is evolving and changing. [2]

The reshaping of our nature in the era of the scientific and technological revolution has reached such a degree that it can be compared in scale and intensity with the geomorphological processes. The man for example with the gigantic mining of minerals and rocks, as well as with the construction works varies considerably the relief of the earth's surface and transforms the landscape. This activity can also have a negative impact, for example with the influence of waste production and pollution increases the change of the chemical composition of the soil, water and atmosphere, by building of energetic units, it varies natural thermal regime. The changes as resulting from these activities often take place so quickly that the man, although has a relatively good adaptation skills, he do not enough adapt to changed circumstances. This creates stressful situations that effect on the regulatory ability of the organism, which is the cause of the greater incidence and widespread so-called diseases of civilization. It follows that the protection of the environment is high on the agenda and needs to be addressed comprehensively. This topic was discussed at all levels and sections of human society. Addressing of these issues is very urgent and requires not only high expertise to use all the knowledge of science and technology, but also the maximum discipline and awareness of people in their activities. [2]

1.2 Environment

The environment can be seen from various aspects, and therefore there is no single, universally accepted definition. In the broadest sense it is possible to define the environment as everything that surrounds us and where we live, and as an environment that allows basic expressions of life and function of living organisms. It is a set of conditions that are in the all biochemical processes of living matter and therefore to not only human, but also all organisms in nature (animals, plants, bacteria, etc.). [8]

In 1967, UNESCO organization adopted the definition of environment of Norway Professor S. Wika, as follows [2]:

"The environment is a part of the world with which the person is in the interactions (interactions), i.e. used by, or affects its adapted".

Philosophically, the environment is seen as a dialectical relationship entity (a person, company) and the object (nature).

The individual components of the environment are interconnected with each other and often direct feedback and form a multi-component system.

The system is characterized by the **behavior** (i.e. dependence between stimuli and responses) and the **structure** (i.e. the organization of links between elements). Each system can be **stable** and **unstable.**

The Earth creates a system of whose elements (by subsystems, whose are the lithosphere, hydrosphere, atmosphere and biosphere. Of each element it can be regarded as a separate system (sub-system), that there are links with other systems. The action on any of the elements of the environment by the influence of mutual relations, raises in the whole system the response, the consequences of which are largely unexpected in view of the frequent lack of knowledge of the behavior of the system. [7]

Man's relationship to the environment should be seen as an open system. One of their lives and activities adopted substances and energy from the outside and gives the products their activities (among them also waste) beyond the limits of his system - into the environment. Open system by the influence of the self-regulation and self-control shows the relative stability to the environment. This feature is designated by the term **"*homeostasis*"**. Human activities' affects into stability system by changing of the diversity of the natural community.

The system of environment from terms of bonds to the terrestrial surface we call as "***geosystems***". The geosystems, which include the presence of certain communities of living organisms and for them favorable environmental factors are called **ecosystems**.

In view of the existence of human society and from character of the measures for the creation and protection of the environment, it is necessary to divide the environment into three categories. It is [6]:

- environment landscape (natural),

- residential,
- working environment.

The structure of the environment is made up of the elements that are in mutual interaction. Some components do not give right to person, but through other, which also form part of the environment.

The components of the environment in terms of genesis can be divided into [3]:

- **natural (natural primordial)**, it means unformed by man,
- **man-made (anthropogenic)**, created by man.

Natural components are divided into [3]:

- inanimate nature (abiosphere),
- wildlife (biosphere).

Artificial environmental issues are divided into [3]:

- residential,
- industrial.

The inanimate nature includes abiotic components of the environment, for example. soil, water, sunlight, air, mineral resources.

The living nature - biosphere includes all organisms, plants and animals from the simple to the complex ones. The smallest element of the environment is a protozoa. The protozoa is qualitatively different and is relatively capable of independent existence. It is part of the component, which is divided into sub-folders. The vegetation as part of the environment is divided into sub-components such as forest, in which the element is a tree. In terms of structural composition environment, the further dividing is irrelevant, since for example the leaf is not able to exist alone. The properties of the component, but also the elements of environment are referred to as factors or agents as well. [4]

Under **environmental factors** means the element of the environment that with the other elements interact together. The **ecological factor** expresses the environmental impacts on the organisms that can act positively or negatively. The environmental factors characterize in their mutual coherence the conditions for the existence of organisms. The each factors interact and affect each other. It is not correct to understand under the factors that ones which impact on the following factors, but on the ones, which affect on the quality of the environment. The quality factors are affecting by pollutants, contaminants of all kinds. [4]

Environmental factors can be divided into [2]:

- **abiotic** - climate, soil, hydrology, etc.,
- **biotic** - factors that reflect the interaction of plants and animals,

- **anthropogenic** - factors that influence human activity (e.g. urbanism, industrialization, water treatment, transportation, communication, etc.).

Under **abiotic factors** are understood environmental factors, on which do not participate the organisms directly and appreciably. These include e.g. soil or climate. The transition to biological agents is mostly smooth, which is seen to impact of land on forest and action of forest on climate conditions. These factors include air, atmosphere, water, soil, heat, light, flow, salinity (salinity), the concentration of nutrients and other chemicals. All kinds of plants or animals are characterized by the environment in which they exist. Thus, for a given type of place, which is formed by certain abiotic factors determine the characteristic species of organisms. Abiotic factor is determined by soil structure, texture, humus, moisture, nutrient content, pH and chemical composition. The importance of light as an energy source need not be separately characterized. [1]

The biotic factors are manifested in the form of certain relations of organisms (e.g. food chain, competitors, reproduction, etc.). They show the interaction between species eco-system. By the coexistence of the two species in the same environment, where exists the interaction between them, and may be positive or negative. For example, negative phenomenon may be reflected in competition, free-riding and ferocity. The positive phenomenon has no negative effect as commensalism (which means the advantage for one partner, but without the benefit of a second), symbiosis (the advantage for one or both elements). [3]

The human intervention in the environment are recently so large that it can result in the distortion stability of the consequences that have large, often have a negative effect on the existence, development and operation of man on earth. Human intervention, given the broad bond and bond together of its ingredients, are not only local or regional, but their effect is usually extensive and effect must be assessed globally.

The importance of international cooperation in protecting the environment, people are aware some time ago.

Environmental issues were monitored at the United Nations level since 1945. Within this organization, there were formed a number of intergovernmental organizations, which in their programs focusing on the care of the environment. [11]

These are in particular [11]:

- **UNESCO** (**U**nited **N**ations **E**ducational **S**cientific and **C**ultural **O**rganization) - Paris 1945,
- **WHO** (**W**orld **H**ealth **O**rganization) - Geneve 1948,
- **FAO** (**F**ood and **A**gricultural **O**rganization) - Rome 1945,
- **WMO** (**W**orld **M**eteorological **O**rganization) - Geneve 1983,
- **IAEA** (**I**nternational **A**tomic **E**nergy **A**gency) - Vien 1957,
- **IMO** (**I**nternational **M**aritime **O**rganization) - London 1958,
- **UNECE** (**E**conomic **C**ommission for **E**urope) - UNO, Geneve 1974,
- **EBRD** (**E**uropean **B**ank for **R**econstruction and **D**evelopment) - London 1991,
- **GEF** (**G**lobal **E**nvironment **F**acility) - Washington 1991,

- **UNDP** (**UN D**evelopment **P**rogramme) - New York 1966,
- **IWA** (**I**nternational **W**ater **A**ssociation),
- **ISWA** (**I**nternational **S**olid **W**aste **A**ssociation),
- **IUCR** (**I**nternational **U**nion for the **C**onservation of **R**esources).

and other organizations and institutions dealing with environmental issues, which are estimated to number more than 5 000.

In particular, it should be noted UNEP (United Nations Environment Programme) Nairobi 1972. It is a program authorized in eco-zoological physiotactical area and coordinate the work of UNESCO, WHO, WMO, FAO and other UN organizations. [1]

Recently, in protecting the environment prepares the requirements for sustainable development (often incorrectly translated and referred to as permanently sustainable development). [10]

Based on the initiative of the United Nations Conference on Environment were created a new organization - the **Commission for Sustainable Development**. It is an intergovernmental organization within the Economic and Social Council, which brings together delegates of 53 countries elected for three years. The Commission's role is to monitor the goals set out in the principal document of Rio de Janeiro, Agenda 21, to be active on all governments to implement the above objectives. At an international level also established **Business Council for Sustainable Development - BCSD** (**B**usiness **C**ouncil for **S**ustainable **D**evelopment), the role of which is from incorporating environmental protection requirements into business strategies. [11]

In conclusion, it should be mentioned other non-governmental organizations active in the areas of environmental protection and human, such as global **Greenspeace, Society for Friends of the Earth**, **VLK** and others.

1.3 Ecology

The **ecology**, later called as discipline of "***biological economy***", which addresses the relationships of organisms to their surroundings and to organisms which live together. About 100 years later defined E. P. Odum (1966) ecology as the science of the structure and function of nature, and humanity considered as a part of nature. Thus characterized as ecology environment biology or environmental science. [1]

Ecology (Greek oikos = home, environment, logos = science) is a **scientific discipline** on the mutual relations of living organisms and the environment, in which living organisms are reproduced. These include life sciences (Fig. 1), but the subject of his investigation and methods is also linked to other natural and social sciences. [10]

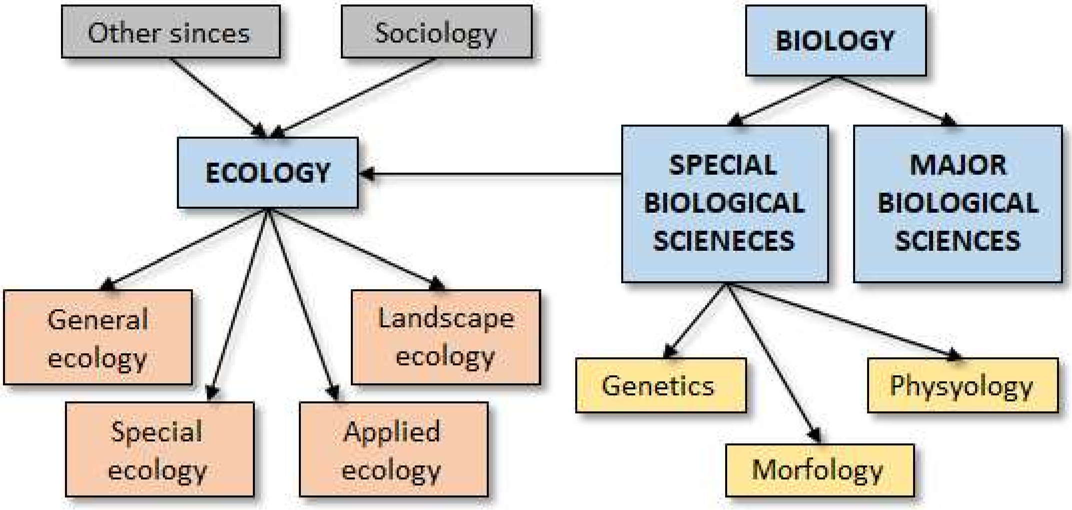


Fig. 1 Ecology and its inclusion among the sciences

The study of relationships between living organisms and their environment can take place at different levels. By studying of the relationships between organisms and their environment groups deals **autecology.** By studies of different groups of organisms associated to a particular unit and their environment addresses to synecology. The synecology is studying biocenosis, ecosystem, whole biosphere and actually represents the core of Ecology. Studying populations, their attributes, and in particular issues fluctuations in population densities in nature deals **demecology** (population ecology). [10]

Th esegmentation of Ecology is a subject to diversity and complexity of different forms of life.

General Ecology - generalized ecological phenomena regardless of nationality systematically studied organisms, it studies general patterns of interactions between organisms and their environment.

Special Ecology - studies the relationship of organisms and different types of environments, respectively. different types of natural ecosystems, for example. forest ecosystems, marine ecosystems, and the like.

Applied Ecology - deals with the practical use of knowledge ecology thus uses the laws, principles, and other ecological knowledge to solve practical problems of the environment.

Landscape Ecology (geoecology), agricultural (Agroecology) and **urban ecology** - watch live and artificial ecosystems, particularly in relation to the creation and protection of the country.

According to the entity distinguishes **ecology of microorganisms, plants (phytoecology)** and **animals (zooecology).** When monitoring the changes of physiological functions and adaptation to changes of environment is called the **ecophysiology**.

In the time dimension we can talk about **paleoecology** dealing with the ecology of the biosphere in parallel with the geological history of the earth and neoecology, which aims to investigate the recent ecological structures, phenomena and processes. [10]

1.4 Ecosystem

The ecosystem is any system, which consists of physical, chemical and biological development of the time-space unit of any size (Lindeman, 1942). An ecosystem is an open system and is a system, in which the secured permanent exchange of substances, energy and information, has a constant supply of energy from the external environment and release energy back. The system is dynamic and stable. [10]

An **ecosystem** is defined as a **functional material system of interrelationships of organisms and the environment in a particular space and time, which has a specific structure, and energy conversion cycle trophic substances autoregulatory mechanism**.

The ecosystem is ongoing exchange of substances between animate and inanimate parts of nature as a result of the interdependence of living organisms and inanimate mineral substances. [10]

Living organism is able to live in the countryside in an environment that is its existential conditions. Terms of life (**ecological valence** of organisms) can suit a variety of organisms. The communities of organisms living together in a particular space called **biocenosis** (Fig. 2).

Within the biota in general they distinguishes between specific groups [11]:

- **phytocenosis** - communities of plants,
- **zoocoenosis** - animal communities.

Each biocoenosis exists in a particular environment, so called **ecotopy.**

ECOTOPY + BIOCENOSIS = ECOSYSTEM

The simplest definition of ecosystem is following:

The ecosystem is any system that contains at least one element alive. A summary of all ecosystems forms the biosphere. The summary of several ecosystems is consisting a country.

Fig. 2 The components of the ecosystem

The ecosystems can be (Fig. 3):

- autotrophic,
- heterotrophic.

Fig. 3 Autotrophic and heterotrophic system [1]

Autotrophic ecosystems (vegetation) create complex organic compounds from simple inorganic substances using light energy (the sun). The system is capable of independent existence (the system feeds on itself). [3]

Heterotrophic ecosystem (animals) is characterized by a predominance of consumption at which the complex organic substances are converted into simpler (the system feeds on other organisms). [3]

The ecosystem is able to maintain himself and create balance. For creating balance all ecosystems need six basic components (Fig. 4) [11]:

- **organic compounds** - at the interface between live and dead parts of the ecosystem (proteins, carbohydrates, lipids, humidity substances and the like),
- **inorganic substances** - introduced into the circulation of energy (carbon, nitrogen, carbon dioxide, water, etc.),
- **climate regime** (temperature, humidity, and other physical factors),
- **producers** - autotrophic organisms, mainly green plants and certain groups of chemotrophic bacteria (e.g. nitrification, iron, hydrogen, sulphur and methane). They are the only ones that know assimilate sunlight and photosynthesis substances (photosynthesis) and create energy-rich organic matter. They are the energetic sources.
- **consumers** - heterotrophic organisms, especially animals living on other living organisms (organic substances), thereby forming a complex biomass
- **decomposers** (resolvers, decomposers) - consist mainly of bacteria and lower fungi. Their core activity is focused on the decomposition (mineralization) of organic matter to the original basic elements bound in the protoplasm, releasing them into the environment, which allows you to reuse them.

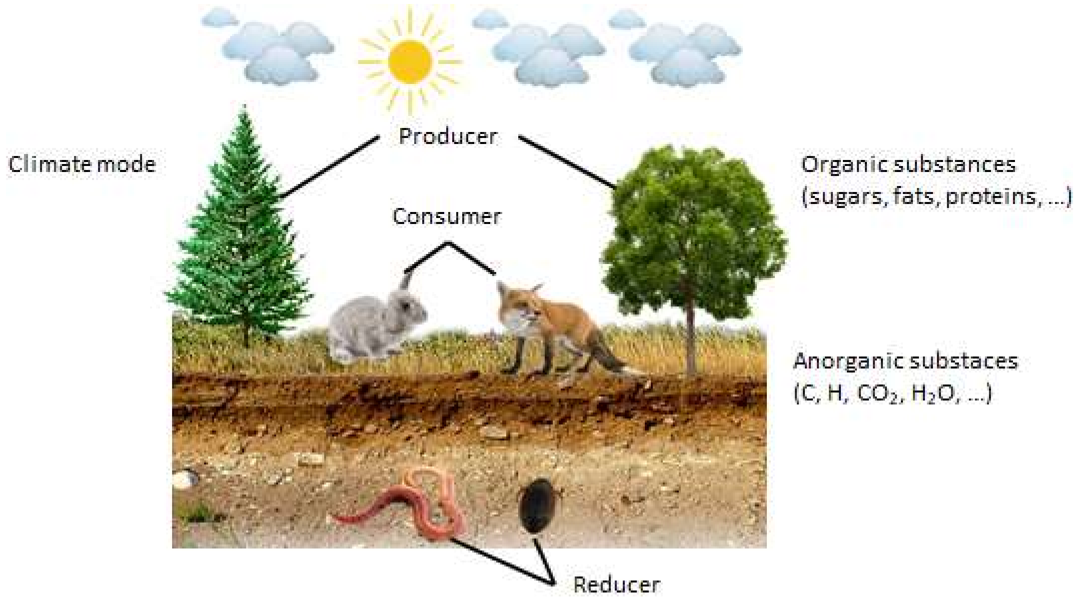


Fig. 4 The components of the ecosystem [1]

All organisms in the ecosystem become bonded directly or indirectly by converting the heat and material between themselves and their environment. These links represent the nutrient or trophic chains that connect the individual the nutrient or trophic levels. Trophic level organisms form having the same dietary requirements, physiology, and using the same source ecosystem. Trophic structure of the ecosystem is an ecological pyramid (Fig. 5) respectively. nutrient pyramids. [10]

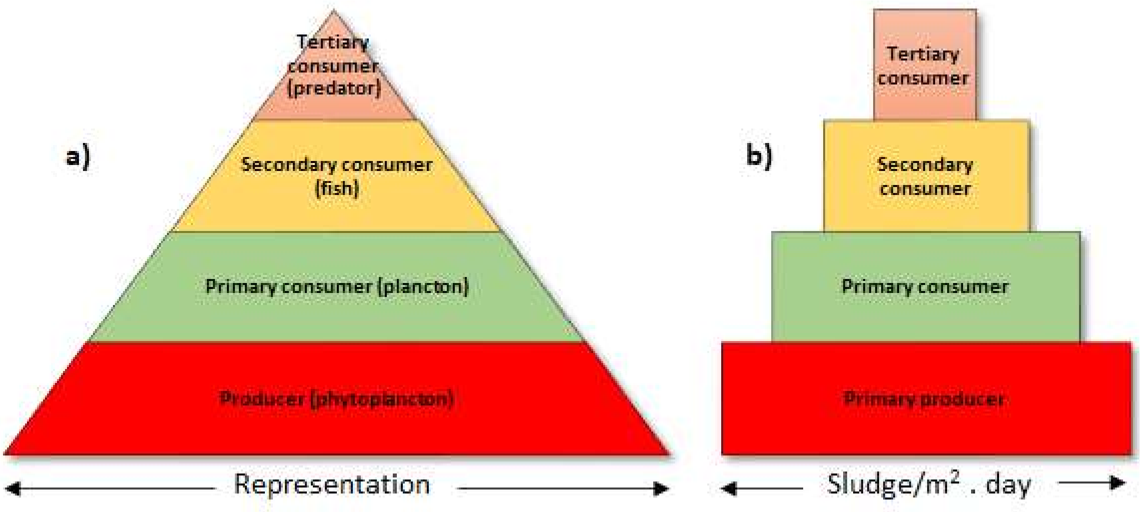


Fig. 5 Pyramid expresses feelings and trophic level ecosystem (a) and the concept of the energy pyramid food chain (b) [10]

- **The first trophic** level consists of plants (producers) that synthesize organic substances and bind a large amount of energy (sunlight).
- **The second trophic level** consists of primary consumers (herbivores, herbivores, partly diversivores) who use the energy generated by producers.

- **The third trophic level** consists of secondary drinkers (carnivores), forming the top of the trophic pyramid of the ecosystem.
- **The fourth trophic level consists** of omnivores (e.g. humans) who consume both animals and plants.

The transfer of substances and energy from the plant as the primary source to organisms consuming and consumed is called **the food chain.** One organism is a source of energy for another. The number of cells in the food chain is usually limited to 4 to 5. [10]

At each conversion of substances between trophic cells, part of the energy is lost. Only a small amount is transformed into the recipient's biomass, which is then available for the next consumer of a higher trophic level. Thus, the greater the amount of energy fixed in biomass, the shorter the food chain. [10]

Food chains are an essential energy relationship of ecosystem biocenosis and are a condition for their formation and energy flow in them. The conversion of energy in the ecosystem corresponds to thermodynamic laws, i.e. the total amount of energy converted remains the same, but at each trophic stage different losses occur, most in the form of heat. It follows from the above that the amount of usable energy is therefore reduced at individual trophic stages. Mass production in autotrophic producers is called **primary production and,** in the case of heterotrophic drinkers (animals), **secondary production.** It is usually measured by units of mass as dry **matter**. A large part of the energy is consumed for various vital functions of the organism (breathing, metabolism, construction and growth of the organism). In large organisms (trees, large animals), the energy consumed by breathing is greater than in algae and microorganisms. [1]

Two basic types of food chains are recognised in terms of structure [1]:

- **The pastevne-prey food chain** expresses the relationship of secondary producers to primary producers that obtain energy from their bodies. Plants are ingered with herbivores and they are ingered by secondary producers of the second and third degrees. The final link of this chain is human or predators. In this group we also include a parasitic food chain, formed by the host, which is an essential source of food, through the parasite to hyperparasites. The body size of consumers in this case decreases and their number increases.
- **The degraded-detritic food** chain binds to organisms breaking down dead bodies and organic substances secreted by organisms. Chains form bacteria, fungi, elements, etc., which form an **edaphone.** Dead organic matter decomposes and mineralizes in the final stage, so biogenic elements return to insuestious nature. The body size of the decomposers decreases, but their population density, on the contrary, increases.

Examples of energy flow in the grazing - prey and decomposing - detritic food chain are shown in Fig. 6.

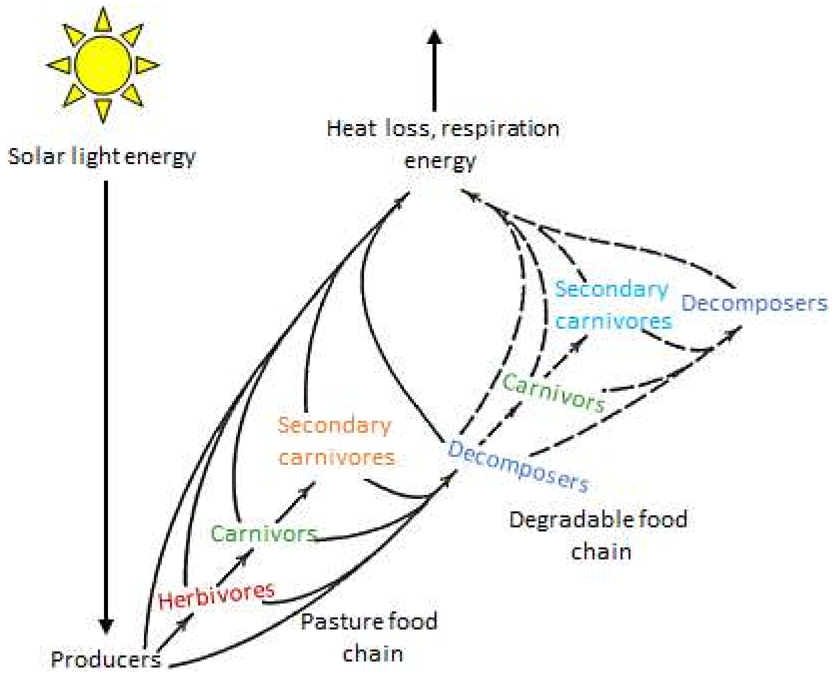


Fig. 6 Energy flow in the grazing-prey and decomposition-detritical food chain

Food chains are interconnected and create a Community-wide food (trophic) network. The total value of primary production does not enter the food chains. Producers consume around 50 % of primary ecosystem production for their life processes. The other half consists of pure primary production, which is available to consumers and consumers. The unused mass of producers is processed by producers. However, this one in species-rich biocenosis passes to other organisms, so the net production is very low. There is no need to supply the ecosystem with additional energy to sustain it - we are talking about the natural balance of the eco-system. [11]

The general model of the trophic structure and energy flow in the terrestrial community is given in Fig. 7.

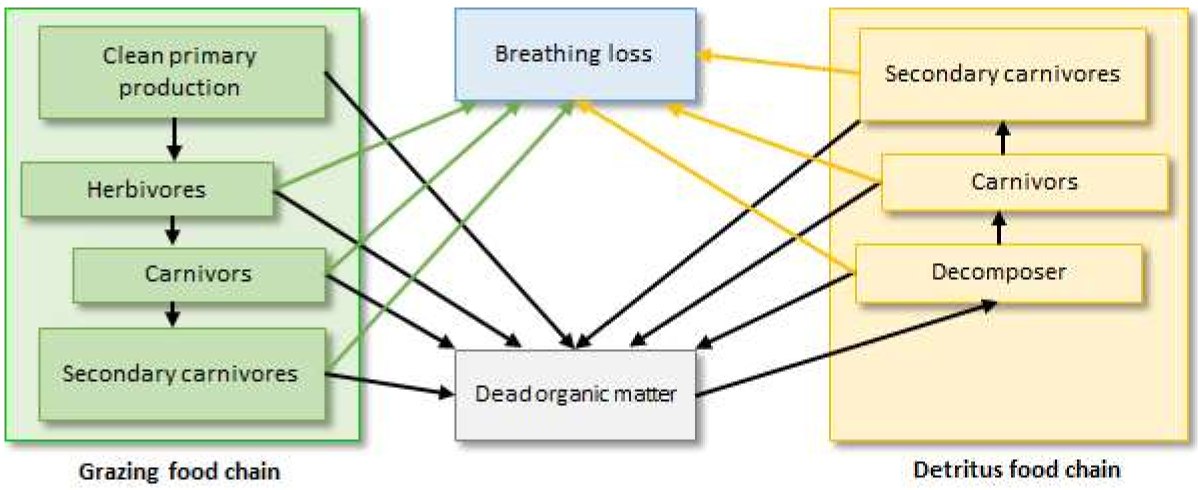


Fig. 7 Model of trophic structure and energy flow

Energy flow in the ecosystem is one-way, power transmission is done by two laws of thermodynamics, namely - **the law of conservation of energy and the law of conversion of energy.** [9]

The ecosystem is characterized by **autoregulation**. Under the self-understood set of massive amounts of "*mechanisms*", causes, relationships, interactions, feedback, natural selection and other environmental phenomena within species, populations and cenosis, which continuously maintain ecosystems within the limits of dynamic balance - homeostasis.

Homeostasis is the ability of biological systems to resist change and remain at steady state. Hemostasis can be called a summary of circulation of substances and energy flows in large ecosystems, which maintains itself and does not require external intervention or impulse. It maintained the flow of energy and cycling of matter. [1]

If it is done the disruption of homeostasis (ecological balance), the situation arises, which is known as the ecological crisis. The **ecological crisis** is a situation, when one of the environmental conditions is necessary for the existence of a system approaches to a limit situation (e.g. temperature drops or rises above the acceptable limit).

If the system will not be able to eliminate, or eliminate the consequences of the limit situation, it is ceased the state of homeostasis, and unless it will not to eliminate the cause of such a situation, there is a collapse of what is known as an **ecological disaster.** [11]

The life on the earth depends on solar radiation and longwave heat radiation rising from the surrounding areas. The most important process of energy flow in the living world is its conversion in photosynthesis. The kinetic energy in the process is changed to the chemically energy bound in molecules of organic substances, thus creating the final product, oxygen. Only a small portion of solar radiation is thus transformed into energy for the biotic components of the ecosystem. [10]

In terms of tidal energy can be divided tecosystems into two groups [10]:

- **natural** - they are able to operate independently of man, the source of solar energy,
- **artificial** - man with energy, especially for obtaining food.

In addition, the human with its activity effects on the energy balance of the ecosystem in that the waste heat concentrated to a relatively small spaces. This concentration of heat along with the increase of dust and CO_2 in the atmosphere causes in urban agglomerations so called. Greenhouse effect (heat antiradiation of atmosphere through absorption of radiation), which raises the temperature above the town of 2 - 3 °C in comparison with others. [3]

In terms of form, the ecosystems are divided into [1]:

- **natural** - forest, bog, lake, river,
- **semi - natural** - under human influence, but naturally formed pastures, meadows,
- **cultural** - intensively cultivated fields, orchards, vineyards, etc.,
- **urbanized** - housing estate, industrial, recreational and other facilities.

According to the size of the ecosystems are divided into [3]:

- **micro-ecosystems**, for example. disproved tree trunk, temporary puddle formed microsystem,
- **mezo-ecosystems** - range of vegetation,
- **macro-ecosystems** - deciduous forest, steppe, urban agglomeration,
- **mega-ecosystems** - are composed of various meso and macro-ekosystem, for example area of the river basin, regional type of landscape,
- **biosphere** - the sum of all ecosystems. It is the parent category of individual ecosystems on the planet.

Natural ecosystems are the result of long-term development, during which more or less the same abiotic environmental conditions occur over time in places characterized by more or less the same abiotic conditions of the environment, more or less the same sequence of communities occurs over time. Individual successive communities affect the abiotic environment, evolve, change their species composition and processes. **There's an eco-friendly succession going on.** The concept of ecology succession then refers to a set of changes in plant and animal communities in a given space and at a given time, which are manifested by the continuous replacement of certain species by other, better adapted conditions. The succession is the result of interactions between biocenosis and ecotope, i.e. between the body subsystem and the environment subsystem. It tends to offset emerging imbalances in biocenosis and ecotope as two opposing aspects of the ecosystem. Each biological system has its own **homeostasis**, which counteres any change in structure within the system, usingfeedback. In succession, the accumulation of organic matter, energy and information (which leads to a change in the system) and homeostasis (which counteracts system change) are counteracted. Homeostasis can only act with feedback up to a certain limit of accumulation. If this threshold is exceeded, a new system is created that is better adapted to the new conditions. After the appearance of the best adapted species, the so-called 100 % **climax community.** In the course of succesional development, the following stages are distinguished [1]:

- **boredom (obstruction) - the beginning of the succession process caused by a certain violation of** the environment (e.g. volcano eruption, human intervention),
- **migration** (colonization) - various viable diasporas (reproductive particles) enter the violated environment,
- **ecesia (restoration) - it is the first settlement of a desolate place or permanent integration into a new community (according to some older authors, it is** the *"seation"* of a plant individual). At this stage, species capable of successfully germining, growing and reproducing will be manifested under given conditions. Species with very rapid reproduction and growth are more likely to survive. In this period, quantity prevails over quality,

- **competition** - it applies species with fewer growth options, but with better ability to survive in conditions of competition. While the young ecosystem is characterised by the development of quantity, the mature ecosystem develops a quality that outweighs the quantity,
- **stabilisation** - the established community is already beginning to change the environment surrounding it. The entire biological process through the individual stages leads to a dynamically balanced state (climax).

The succession stages remain constant for some time, change only gradually and can persist for different lengths of time without substantial change - one year, decades, or they can remain without further developmental change even permanently. The stages are continuously interlinked, while at the same time species of the previous stage may also be present in the Community as new as a result of new environmental conditions and which are carriers of a new stage. [2]

The basis of the energy flow in an ecosystem is a photochemical reaction which will transform inorganic substances to organic substances - **photosynthesis**. Motor power is the energy of solar radiation, which is converted to chemical energy and heat. [5]

The individual components and the relationships in the ecosystem are clearly shown in Fig. 8.

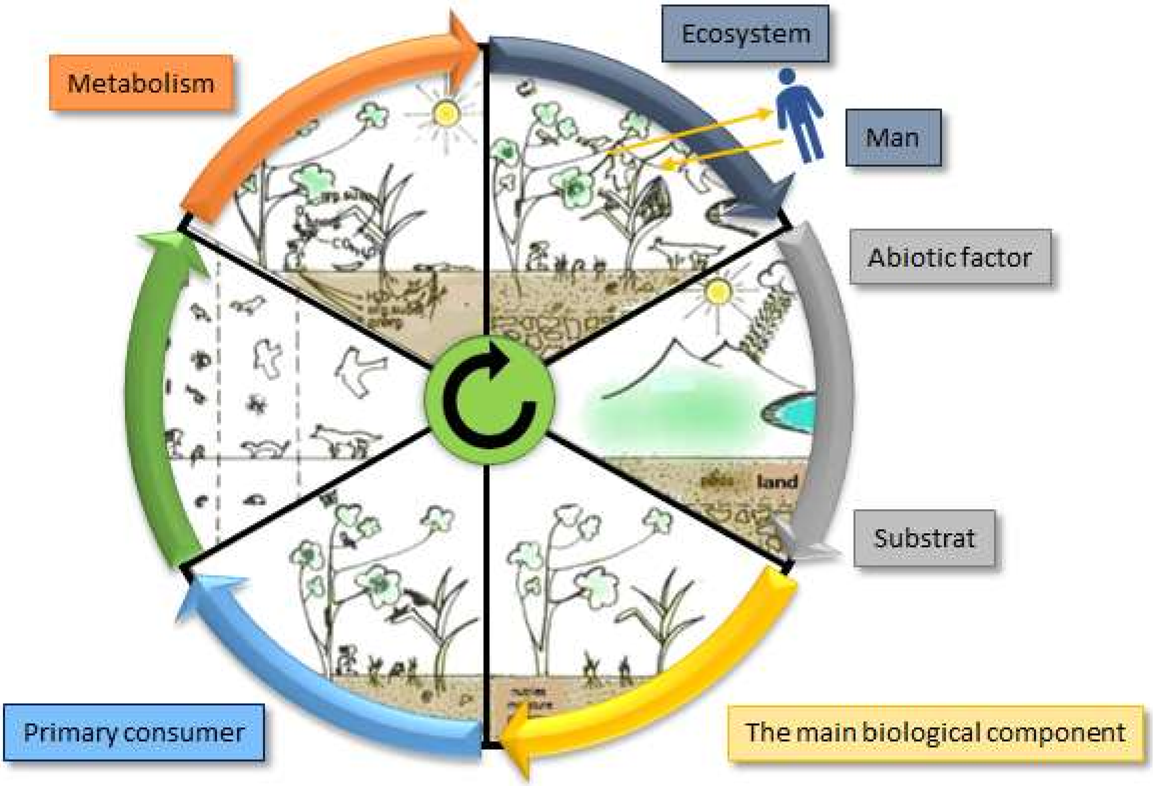


Fig. 8 Ingredients and relationships in an ecosystem

In recent years, more and more ecosystems are chemized by human activity. The rapid development of energy, industry, chemistry, agriculture, transportation and other industries brought about the increasing demands on natural resource exploitation. Their excessive plundering and exploitation leading to serious conflicts between society and the environment in which the company lives and will live. [5]

It is therefore necessary to look also paths of economic development, which is consistent with a healthy environment. [5]

A special case is the ecosystem environment of human society (human). Biologically it is necessary to consider the relationship of man to his environment as an open system, which needs to its run a lot of energy.

1.5 Environmentalistics

One of the roles of biology is to determine the carrying capacity of ecosystems, which humans cannot exceed to avoid damage to their functionality. Therefore, the knowledge of man is very important to research on patterns that can be studied only in protected areas (reserves), which are only slightly damaged by human activity. Environmental problems depend on the degree of social development. Their combined effect is global in nature. On the basis of the areas they can be divided into three groups [1]:

- technical and economic problems,
- environmental problems related to air environment,
- social problems stemming from the concentration of the population, its habits and relationship to the environment. Here in troubleshooting affect the human sciences.

It is generally accepted knowledge that the solution to these problems can greatly affect the solution to the problems the previous two groups. Environment is also strongly influenced by human behavior. [10]

Choosing of the wrong tactics of the man in the relation to nature (**physiotactics**) at local, regional and global scale directed to significant environmental damage, thereby jeopardizing its own existence. Conversely, correct and versatile thought out physiotactics protection and rational use of natural resources in finding and applying the possibilities of recovery in the local, regional and global scale give on towards to a sustainable life. This will also include in the care of the environment protection, development and management environment of organisms, including humans.

Physiotactics are mainly influenced by the following factors [11]:

- climate, relief, drinking water sources, soil fertility, proximity to the sea,
- the state and development of industrialisation and urbanism,
- the state of the environment and the dynamics of its permanent and temporary changes,

- the level of knowledge of nature and its legalities, natural resources and their usefulness,
- use of renewable and non-renewable natural resources,
- morbidity and the possibilities for reducing it,
- provision of nutrition and other biological, social and economic living needs of humans,
- policy, philosophy, religion, law and the overall principles of behaviour adopted,
- the degree of development of the company and the level of its culture.

Physiotactics, therefore depends on the specific political, economic, social and environmental situation and the health status of the population. The main task of environment is therefore on the basis of good physiotactics develop and implement measures aimed at eliminating the consequences of inappropriate and harmful impact on the environment. [10]

Philosophical foundations of Environmental Sciences is **environmentalism**, which creates a thumbnail of the world, examining its general principles and laws, identifies ways of harmonizing relations of nature and man at the same time the principles of behavior and value differentiation. The aim is to preserve the environment for the development and survival of humanity and other organisms. **Environmentalist** is therefore a person, who is professionally or voluntarily engaged in applying the correct physiotactics in practice. Professionally it can be an ecologist, geographer, geologist, farmer, water engineer, forester, architect, lawyer, energy, economist, hygienist, teacher etc., regardless of age. [3]

As the social sector has already environmental broad scientific base especially in ecology, geography and sociology, while it is necessary the philosophical generalizations, legal codification and transfer to the economic, technical and natural sciences with direct application in practice. Environmentalistics of 21-st century becomes the sphere of human interest, based on the age-old existential human needs, together with the economic sphere and the social sphere. The status of these three spheres and their harmonization will identify opportunities for sustainable development and life. [1]

Many principles of hygiene and morals, respect for nature and the human behavior, which we now call the **environmentalist principles,** already in the distant past were applied in different civilizations, cultures and religious communities. These principles have significantly expanded especially science knowledge. [2]

Environmentalism, which forms the philosophical foundations of environmentalistics, looking for opportunities for synergies between the man and the rest of nature, generalizes the experience and knowledge of the Environmental Sciences, restates the principles, methods and procedures leading to more sustainable life on Earth in its biological diversity. For example, environmental alliance "*The Closing Circle*" (1971) indicated the two fundamental laws of environmentalism [10]:

- Nature is more complex than we know, and probably much more complex than we can know.
- Nature knows all the best.

Other propositions based on ecology are [3]:

- The biosphere everything is related to everything.
- Maximum cannot be optimum and optimum cannot be maximum (boomerang effect).

A complex theoretical and practical foundations for the development of Environment as social sectors began to form in the more sophisticated countries until the late sixties and early seventies, in other states and in internationally touchstone about five to twenty years later. Environmental supports and uses reasonable tactic interference in nature and in the human environment and other organisms, as well as to all natural resources. Physiotactics anticipates the possible consequences of interventions in nature and the human being, and its components. [1]

Humans are essentially interested in apart from the biological essence, three aspects of life - economic, social and environmental, which limit the interconnection of the existence and development of the individual and the population. This is related to the anthropocentric understood **sustainable development** (Sustainable Development), subsequently a **sustainable future** (Sustainable Future), ecocentric understood **Sustainable Living** (Sustain-able Living) and **sustainable production** and **consumption** (Sustainable Production and Sustainable Consumption). [4]

Environmental performance will be in a few years and probably normally much larger than today applied in legislation outside of the environmental law. It will, of course, a part of the consideration and economic steps. Similarly, in real life the man will in critical situations or whole planet to think quite otherwise. But it will need to redouble their efforts for the right to a favorable environment has become a real fundamental rights for all people of this planet.

The external environment is a natural interaction of three spheres, namely the atmosphere, hydrosphere and pedosphere, as well as their interactions with the biosphere. Multiplicity of functions between the spheres is significantly affected by environmental pollution. Ecological stability is directly dependent on the degree of pollute.

Environmental risks associated with environmental pollution are heavily dependent on the depth of the responsibility for the state of the environment, as manifested by how we deal with different sources of risk. To secure an environment that is suitable for the healthy development of the population and society must learn to identify and assess the various risks of various human activities, recognizing the critical points of vulnerability of the environment in time and space, and manage anthropogenic activities so that we as to reduce pollution. According to one definition, pollution is bringing more such physical, chemical and biological risk factors in the environment due to human activity, which by their nature or quantity foreign to the environment. [9]

Sources of pollution of environment are by nature natural or anthropogenic. Both groups comprise a sizeable range of very diverse sources, catchment boundaries which cannot always be accurately distinguished.

Natural resources that originate from geo-production (minerals, ores), the components of the environment (air, water, soil) and organic production, is processing by industry for goods and services for comprehensive human consumption and ensure the necessary reproduction of social forces. [10]

Techno-sphere has no disposed with non- waste technological processes or finished or semi-finished products, which have not always necessary environmental parameters. Emissions and waste from technological processes and products during use or survival after returning to the natural environment (Fig. 9). These energetic -material emissions from anthropogenic activities, predominantly from the technosphere, are the cause of deterioration and damage to the environment.

Anthropogenic activities affected ecosystems ultimately disrupts the delicate balance of organisms and abiotic factors or activities taking place in the environment. Ecosystem due to anthropogenic activities may be adapted, but only to a certain limit. To understand the effects of human activities on the environment is therefore necessary to understand the nature of the ecosystem. The first step in reducing the adverse impact of human activities on the environment is to understand the relationship between the action and consequences, precisely by environment. The second step is to control or limit the effects of human activities on the environment, through the environmental technology, which as interdisciplinary, practice-oriented industry, seeks to preserve natural resources. This includes the development of equipment and processes that allow to implement measures to long-term and final settlement of issues and also the development of monitoring devices. It focuses on the engineering addressing the key issues relating to the prevention and remedying damage already damaged the environment (**environmental engineering).** [1]

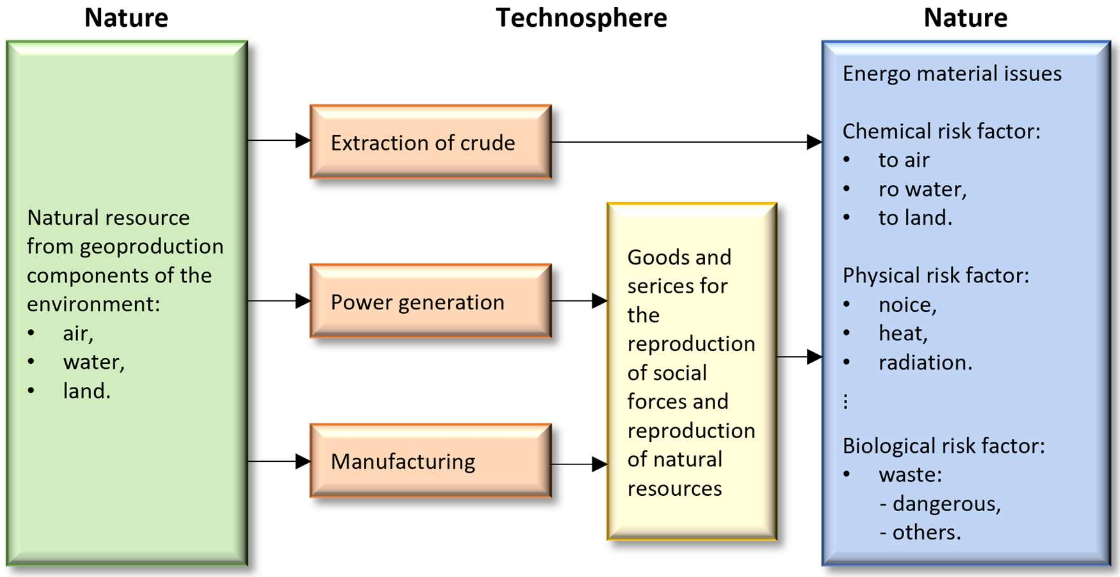


Fig. 9 Material and energy flows in the reproductive process

By inclusion in the overall production cycle, technologies to protect the environment can divide into three groups [10]:

- **Technologies that are complementary to existing processes** (e.g. the disposal of waste products, such as sweetening process or disposal NO_x).

- **Protecting the environment by integrating production.** It is basically the optimization of the components of the manufacturing process, or the completion the of change process.
- **Total environmental protection.** The final target in this case requires that the raw materials and waste products are maintained in a closed cycle. In practice, this means that for each industry or industrial establishment shall be drawn material balance of production and waste products and on the basis of the balance shall assess the impact of the technology on the environment.

1.6 Engineering and Environment

Most people care about the environment. But what exactly does that mean? When we talk about "*environmental problems*" that need to be addressed, what do we have in mind?

The "*environment*" can mean different things to different people. The unabridged Random House dictionary defines *environment* as "*the aggregate of surrounding things, conditions or influences, especially as affecting the existence or development of someone or something*". What we have in mind when talking about the environment can make a big difference in the way we approach the subject and in how we formulate or frame environmental issues and problems. [7]

In this book the term *environment* will generally refer to the physical environment that surrounds us. This includes the air we breathe, the water we drink, and the lands, oceans, rivers, and forests that cover the earth. To an increasing extent it also includes the buildings, highways, and modern infrastructure of the urban settings in which a growing proportion of the world's population resides. The state of this physical environment directly and indirectly affects the viability of all living things on the planet - the people, plants, birds, fish, and other animals that we care about. The welfare of these living things motivates most environmental concerns. [7]

This chapter provides a brief introduction to some of the major environmental themes that are discussed later in the text. These themes emphasize areas where engineers play a major role in solving (as well as creating) environmental problems. For perspective, we begin with a broad overview of environmental impacts and the role of engineering. [6]

1.6.1 Framing Environmental Issues

We know from the study of geology, biology, and other natural sciences that the earth's environment has been changing since time began. What motivates modem concerns about the environment is the expanding role that human activities play in accelerating environmental change. [1]

The Fig. 10 illustrates schematically how human activity influences the environment. At the most basic level, human demands for food and shelter mean that some living things (plants and animals) will be killed or harvested for food, and some natural resources, such as trees, will be used to build structures and provide energy for shelter, cooking, and warmth. These basic demands of human survival thus give rise to an environmental impact. As human populations increase, more and more land is altered to provide settlements and to support activities such as agriculture, industrial processes, and transportation systems. As people become more affluent, their demand on the earth's resources grows far beyond the basic needs for survival. [10]

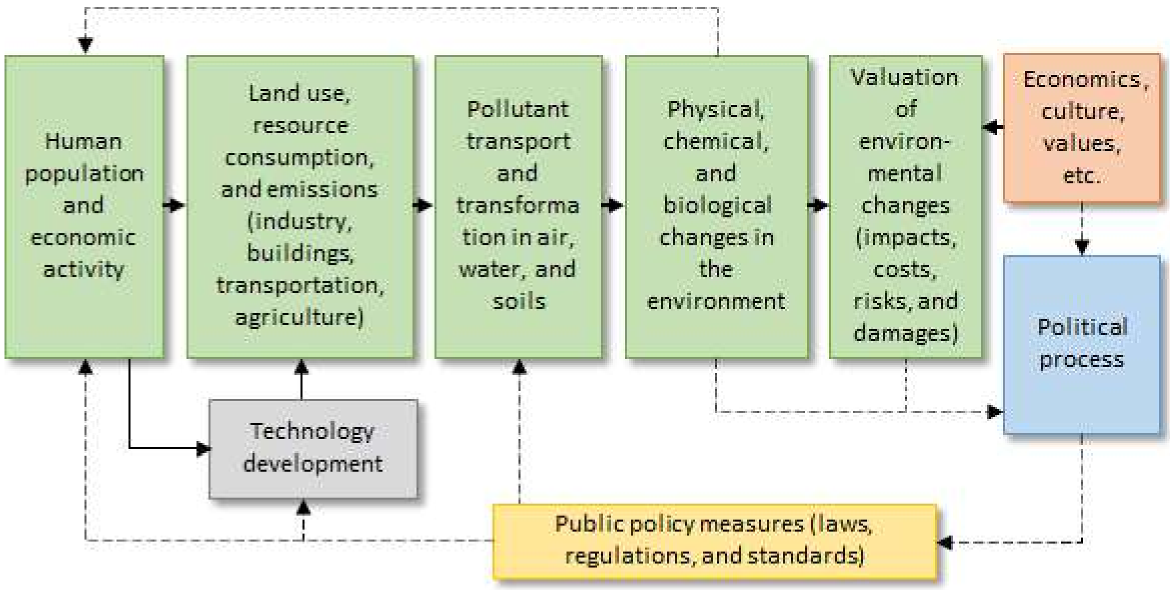


Fig. 10 A framework for environmental impact assessments. Solid lines show the path of primary or initial impacts; dashed lines show the major feedbacks and responses to these impacts

In addition to altering the landscape, diverse human activities give rise to various types of waste emissions or *residuals* discarded to the environment. Modem examples include air pollutants from factories and automobiles, water contaminants from manufacturing processes, solid wastes from household and municipal activities, and pesticides used in agriculture. [11]

Many of the wastes or pollutants discharged to the environment are subsequently transported and chemically or biologically transformed over time and distance. For example, gaseous sulfur dioxide emitted from the tall chimneys of coal- burning power plants is partially converted to fine sulfate particles by chemical processes in the atmosphere. This mix of sulfurous gases and particles leads to *acid rain*, which can damage lakes and forests hundreds of miles away. Similarly, many types of organic wastes from factories and households are discharged to rivers and streams, where they are transformed by biological reactions that deplete the oxygen dissolved in water. A deficiency of oxygen directly affects the viability of all aquatic species. Other examples of physical, chemical, and biological changes in the environment due to human activities are shown in Tab. 1. [5]

Historically, the most pervasive environmental changes caused by people have been related to land use - particularly the clearing of forests for agriculture and urbanization. Now, in the modem industrial era, the added impacts of emissions from modem industrial technology are rapidly accelerating the process of human- induced environmental change.

Are all changes in the environment a reason for concern? Isn't the environment always changing, and aren't many of these changes beneficial?

Tab. 1
Some examples of environmental change from human activities

Human Activity	Physical Changes	Chemical Changes	Biological Changes
Land and water use for housing, agriculture, industry, transportation, and recreation.	Deforestation and other alterations of landscapes (e.g., changes in terrain slope, vegetation coverage: pavement); alteration of waterways (e.g... flooding, dams, changes in river channels: drainage of wetlands).	Changes to chemical constituents of soils and sediments (e.g.: increased acidity and turbidity of waters, removal of nutrients from soils).	Changes in the viability of plants: fish; animals, and microorganisms due to altered habitat and chemical constituents or concentrations, possibly leading to species succession. extinction, migration, or disease.
Emissions or discharge of chemical substances to air, land, and water.	Changes to the built environment (structures such as buildings, bridges, monuments, etc.) from deposition and chemical attack caused by emissions such as soot deposits, acid gases, and liquid chemicals.	Increases in the concentration of emitted substances in the air, water, and soil: other chemical changes resulting from secondary reactions (e.g., buildup in urban areas) ozone.	Injury or illness to people, plants, and animals from exposure to and/or accumulation of chemicals and their derivatives.

The answers to such questions are not always simple. In general, our greatest concern is over environmental changes that may harm us or affect our welfare. This is illustrated by the feedback loop in Fig. 10 between environmental change and human activities. This interaction is complex, because some environmental changes that are beneficial, in the short run may have adverse consequences later on. In preindustrial societies, for instance, the clear-cutting of forests to support agriculture was essential for providing food for a growing population. Over time, however, the continued depletion of forests often led to soil erosion, loss of soil nutrients, and a subsequent inability to sustain agricultural production. As a result, many communities disappeared or were forced to migrate elsewhere. [3]

In today's industrial society, many air pollutants and water contaminants entering the environment as byproducts of modem technology are widely recognized sources of human illness and ecological damage. More subtle or indirect impacts, such as the effects of long-term global warming from anthropogenic emissions of carbon dioxide and other gases, are less clearly defined at the moment, but raise new concerns about the longer-term effects of energy use and industrial activities. [5]

Of course, not all people agree on whether a particular environmental change is cause for concern. For example, the clearing of wooded lands to provide space for a new farm, factory, shopping mall, or housing development is commonly seen as a beneficial change that allows people to lead better, more productive lives. Others, however, may view these same changes as destructive of natural habitats for vegetation and wildlife that have intrinsic value and are part of natural ecosystems that affect our long-term welfare and survival. So who's right? And if both views have merit, how do we weigh the tradeoffs and make a decision?

In democratic societies, the political process is how decisions are made as to whether actual or potential changes in the environment are of sufficient concern to adopt policy measures (e.g., laws and regulations) to prevent, alter, or reverse these changes. Some notion of the damages or risks that will be avoided by taking action is one essential element of the decision-making process. Providing such information is an area, where Science and Engineering often play a key role. Ultimately, a host of other factors also influence community and national decisions about environmental policies. As shown in Fig. 10, such factors include the influences of culture, societal values, and economics. [11]

Because of these factors, priorities and preferences for environmental protection often vary from community to community and from country to country. For instance, a nation struggling to provide its citizens with the basic necessities of life is unlikely to be as worried about wilderness preservation as a wealthy nation. Nonetheless, over time societies tend to address environmental problems in an order roughly equivalent to the relative risks they pose. Often this starts with basic health issues like water quality and sanitation, then broadens (often in tandem with economic development) to include other issues of health and environmental quality. [1]

Environmental policies also are often based on concepts of fairness, or equity, such as the idea that all citizens have a right to breathe clean air. In other cases, the symbolism or basic ethic of environmental protection is most important, as with the protection of endangered species. Because environmental policy often has significant economic implications, it is almost always influenced by private interests as well as the public interest. [5]

At all stages in the policy development process, one important approach is to look for policies whose benefits clearly outweigh the cost of measures taken. An economic analysis of costs and benefits is sometimes employed to evaluate the merits of proposed policy measures. In many cases, however, putting a dollar value on expected environmental and health benefits is especially difficult and controversial. A less controversial approach is to identify measures that are lowest in cost. The adoption of such measures often serves as an initial basis for policy actions. [11]

If environmental protection measures are adopted, their influence might be felt in a number of ways. For example, some measures might alter human behavior by forbidding certain types of activities, such as the dumping of wastes or drilling for oil in pristine areas. Other measures might require the use or development of new technology to abate harmful emissions to the environment. Thus, new cars might have to be equipped with catalytic converters to reduce air pollution and cleaner technologies may be demanded to generate electricity. To an increasing extent, environmental protection measures in the form of standards and regulations have established new constraints on the design and deployment of modem technology. Environmental policies thus shape the development of technology in directions that reflect the goals and preferences of society. [3]

1.6.2 The Role of Engineering

Where do engineers fit into all of this? The Fig. 11 suggests how pieces of the environmental puzzle map roughly into the traditional bailiwicks of undergraduate majors or disciplines. Engineers are primarily involved in problems related to technology development and deployment. These include designing, developing, and building the cars, computers, television sets, and other consumer products that people enjoy. Engineers also design and build all the manufacturing processes, industrial technology, and transportation infrastructure needed to extract, transport, and refine raw materials; fabricate products; and distribute the goods and services of modem societies worldwide. In order to predict the consequences of technology deployment, engineers, along with scientists, also are involved in the study of how pollutants are transported and transformed in the environment. Thus, in the broadest sense, engineers are concerned with - and often responsible for - a wide range of activities that directly or indirectly contribute to environmental change. [5]

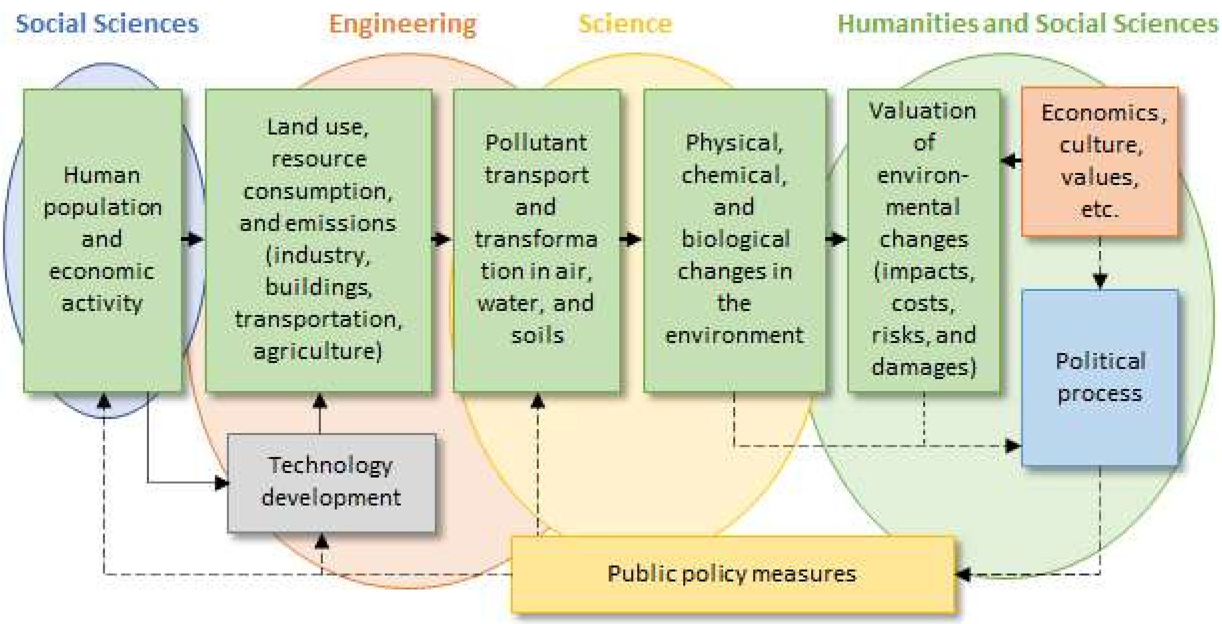


Fig. 11 Mapping of environmental topics into traditional undergraduate disciplines [5]

From this discussion we see that the sources of anthropogenic environmental change fall into two broad categories [11]:

- *changes associated with land use* (including depletion of natural resources),
- *changes induced by emissions* or residues from products and industrial processes.

Engineers have responsibilities for both types of impacts, especially the latter. For example, chemical and mechanical engineers design the petrochemical refineries, paper mills, power plants, and myriad other processes at the heart of industrial societies. The design and operation of these processes directly determine how much air pollution, water pollution, and solid wastes are produced and released to the environment. The same is true for the water treatment plants designed by civil engineers, the microchips developed by electrical and computer engineers, and the steel mills, aluminum smelters, and extraction processes developed by metallurgical engineers. [1]

In addition, all of the consumer products we use (and eventually discard) - such as batteries, toasters, light bulbs, refrigerators, computers, and automobiles - are a result of engineering design decisions that impact the environment. For example, the engineering design of an automobile, including the choice of materials, the type of engine or power plant, and the manner of construction, determines the type and level of air pollutants that are emitted over the life of the car, the amount of fuel required, and the type and quantity of solid wastes that must be disposed of at the end of the car's useful life. Thus, the way engineers design products and processes plays a big role in creating as well as solving environmental problems. [10]

What about other types of environmental concerns, such as species extinction from the clearing of tropical forests, drilling for oil in the Arctic, or the ecosystem impacts of wetlands development? Do engineers also have a professional role in these types of issues?

Yes, they do. These are examples of environmental changes associated with land use. Here engineers also play a key role, but often less directly. The environmental impact of land use decisions is a broader societal issue that involves not only engineers, but a host of other professional and political interests as well. Thus, while the technical design of an automobile, a power plant, or a steel mill is primarily an engineering responsibility with direct consequences for emissions to the environment, decisions about *deploying* that technology - that is, *whether* to use it, or *where* to put it, or *how many* to deploy - typically extend beyond the realm of engineering practice. Often those decisions fall in the domains of city and regional planners, government regulatory agencies, and other groups responsible for review and approval of land use proposals from developers, landowners, corporations, and others. Thus, although engineers frequently play a central role in formulating recommendations with respect to land use - such as where to locate a highway, build a dam, or deploy an oil rig - the process of arriving at a final decision transcends engineering. Throughout this process, however, engineers are intimately involved in defining, collecting, and interpreting the data needed to assess the environmental implications of major land use decisions. [2]

1.6.3 Approaches to "Green" Engineering

Think about something you've thrown away recently. Maybe it was something small like the alkaline batteries from your CD player, or something big like an old refrigerator or an old used car that finally died. Now, imagine that you were the engineer responsible for designing and manufacturing that product. The laws have suddenly changed, and now, you must take back all of the discarded product and be responsible for its environmentally safe disposal. If you had known this in advance, would you have designed and built the product in the same way?

This scenario is not at all far-fetched. In Germany, manufacturers like IBM are now required to take back all of their discarded computers, which contain quantities of toxic metals used to manufacture circuit boards and other electronic components. The cost of dealing with this enormous problem has caused IBM to completely rethink the way it designs, manufactures, and ships its computers. The result has been a substantial reduction in environmental impacts throughout the product life cycle, without compromising the product's performance or adding to its cost. Indeed, many changes have *saved* money. [9]

This is but one example of how the philosophies of green design, pollution prevention, and industrial ecology are changing the way engineers do their jobs. Here we give a brief introduction to these concepts.

1.6.3.1. Sources of Environmental Impacts

Over the years, the authors of this text have been asking freshman engineering students to define what engineers do. Invariably, one of the first answers is that engineers "*solve problems*". True. But doctors, lawyers, mathematicians, and many other professionals also solve problems. So what is it that makes engineering distinctive? Upon further reflection, students conclude that a unique characteristic is that engineers "*build things*" and "*make stuff"* that serves society. [4]

Let us use this definition to refine our thinking about the types and sources of environmental impacts that engineers most directly influence. As discussed in previous chapter, many environmental concerns are related to atmospheric emissions, water pollution, solid wastes, and natural resource depletion. If we step back and ask about the *sources* of these impacts as they relate to the engineers who design, analyze, and "*build things*", three major categories emerge: materials selection, manufacturing processes, and energy use. [5]

Materials Selection Anything that engineers design and build - be it a refrigerator, car, chemical plant, or circuit board - has to be made out of something, and the choice of that "*something*" will directly affect the environment. After all, the material has to come from somewhere, and eventually it all tracks back to the environment. [1]

Not only the choices of materials, but also the quantities needed, are important variables that engineers can influence. Thus, knowing something about how the use of different materials may affect environmental quality is important for all engineering disciplines. Two key questions to keep in mind when selecting materials are "*Can I use alternative materials that are environmentally preferable?*" and "*Can use less material without compromising function or reliability?*"

Manufacturing Processes This topic refers to the methods that engineers devise to turn raw materials into finished materials and products. It starts with the raw materials dug out of the earth's crust, and continues through the stages of refining, transport, transformation, and assembly into final products. In most cases, every step along this chain releases waste materials to the environment in the form of air pollutants, water pollutants, and solid wastes. Historically, much of what went on in the field of environmental engineering involved developing additional technology and methods for cleaning up the problems created by primary manufacturing and processing technologies. [11]

Many engineering students are not exposed to manufacturing methods because college curricula have become increasingly devoted to the fundamentals of analysis and design. But if you get to actually build something in a project course or design class, stop and think about how the material you're working with was produced, how it got its shape, and what environmental impacts resulted from those processes. The problems at the end of this chapter will introduce you to some of these processes. [8]

Energy Use This source of environmental impacts is perhaps the most pervasive and most important of any that engineers deal with. Energy is vital for life and for an economy, and the quantities and types of energy that a society uses directly affect environmental quality. [8]

Energy use encompasses everything from the heating and cooling of homes and buildings, to the electricity that runs modem computers and appliances, to the gasoline and other fuels that power our transportation system. The manufacturing processes discussed earlier all require energy to perform their tasks. Most of the world's energy today comes from fossil fuels - oil, coal, and natural gas - and when these fuels are burned or converted to electricity the environment is affected. Nuclear power leaves a different kind of environmental legacy, and even renewable energy sources like hydroelectric, biomass, solar energy, and wind power are not without their adverse environmental consequences.

A good rule of thumb is that any engineering improvement that reduces the energy required for a particular service will be beneficial for the environment. Thus a desktop computer designed to use 400 watts of power instead of 800 watts, or a car that gets 30 miles per gallon (mpg) instead of 20 mpg, will be environmentally friendlier. Switching from one energy form to another - e.g., from gasoline-powered cars to electric-powered cars - is a lot trickier to deal with. As we shall see in later chapters, the environmental consequences may involve trade-offs that are difficult to evaluate. [8]

1.6.3.2. A Life Cycle Perspective

An *environmental life cycle assessment (LCA)* provides the "*big picture*" of how engineering decisions in any particular area affect the environment. Fig. 12 illustrates the connections among the stages commonly involved in building and creating goods to serve society. [9]

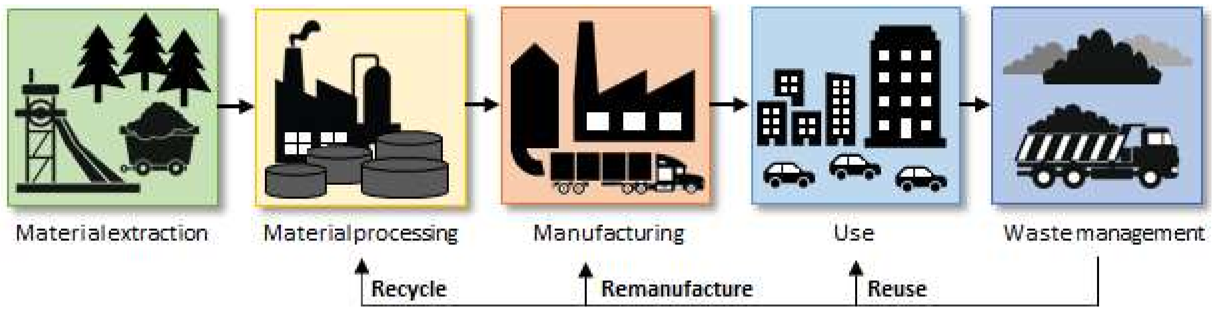


Fig. 12 Stages of a product life cycle. Environmental impacts occur at all stages. These impacts can be reduced by engineering designs that change the type and/or amount of materials used in a product; by creating more efficient extraction and manufacturing processes; and by improving the recovery and reuse of materials and energy at the end of the product life

Environmental impacts occur at each stage as a result of materials consumption and transformation, and the use of energy. [3]

Traditionally, most engineers focus on only small pieces of this overall system. But this is starting to change. Environmental awareness has made it clear that all stages of a product's life cycle must be considered in finding ways to reduce environmental impacts. Improvements result from creating cleaner, more efficient manufacturing operations; from reducing the energy and materials needed for use of a product; and from improving the recovery of energy and materials during waste management. Life cycle assessments are thus an important tool in implementing the concepts of green design, pollution prevention, and waste minimization that are becoming fundamental paradigms of good engineering practice. [1]

1.6.3.3. Industrial Ecology and Sustainable Development

The perspectives of a life cycle assessment provide the foundation for a more comprehensive view of design for the environment that has come to be known as *industrial ecology*. This term has gained popularity in recent years as an embodiment of the environment principles that should be reflected in engineering design. As defined by Graedel and Allenby (1995),

> **Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems, view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital.**

This view is very much in keeping with the concept of *sustainable development,* which also has been widely popularized in recent years. As originally defined by the World Commission on Environment and Development (WCED, 1987),

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

This statement reflects a strong moral and ethical position about our own responsibility to future generations. But how does one operationalize this goal? Allenby (1999) suggests that the application of industrial ecology principles offers a means by which sustainable development can be approached and maintained. In more practical terms, industrial ecology is based on the concept that natural systems tend to recirculate and reuse materials, thus eliminating or minimizing the production of wastes and the use of energy. This offers a lesson and a path for the development of industrial systems and technology. [11]

Another embodiment of industrial ecology principles was offered in a recent National Research Council study (NRC, 1996) that suggests that industrial ecology should include [1]:

- circulating and reusing material flows within the system,
- reducing the amount of materials used in products to achieve a particular function,
- protecting living organisms by minimizing or eliminating the flow of harmful substances,
- minimizing the use of energy and the flow of waste heat back to the environment.

The world "*progress*" in the devastation of the environment is significantly forward. It is the task of the Environmentalistics to familiarize themselves with the current state of the environment, to assess the starting position and seek redress not only protection, but also in making health nondeleterious environment.

2 ABIOTIC AND BIOTIC ENVIRONMENTAL FACTORS

The basic conditions in order to be regarded as a living system is the presence of several basic attributes (living thing must have certain characteristics). For basic characteristics are considered [11]:

- **metabolism** (material changing),
- **irritability** (ability to respond to internal and external stimuli),
- **the heritance of traits and reproduction** (reproduction) - the ability to store and transmit hereditary information it down from generation to generation,
- **development** (evolution) - the ability to adapt to changing environmental conditions and successfully they live through gradual changes of genetic information.

Most living systems has cellular organization and the ability to self-regulation. Organisms are adapted to a whole range of conditions. In nature, however, none of the environmental factors occur in isolation, always a combination of a simultaneous presence of a wide range of effects. This is particularly the effects of inanimate nature - abiotic, i.e. physical and chemical and biotic influences which constitute a direct or indirect effect of other organisms, whether or not of different kinds. An important natural factors is also time. Basic conditions are species specific conditions (each organism requires a quality life for other conditions), but must pay at the same time. The main limiting factor is always the one who is the minimum (i.e. Liebengov Law of the Minimum) [11].

2.1 Abiotic Environmental Factors

Abiotic environmental factors may be of a physical nature (radiation, temperature, light, pressure, air, air flow), or chemical (aqueous medium of saline, oxygen, etc.). [14]

2.1.1 Physical Environmental Factors

One of the most important factors affecting life on Earth is the **sun radiation**. It is a wide range of different types of radiation (electromagnetic radiation), which are as diverse wavelength (0,0001 mm, of the electromagnetic component of the cosmic ray, to over 15 km, which are long "*radio*" waves). The life of most organisms is limited primarily by **temperature.** Life processes can take place according to current knowledge in the temperature range from about - 200 °C to + 300 °C. [17]

Most organisms shall be borne by temperature differences only in a certain limited extent. The sun is the source of **light**. The light ray is an essential source of energy for the basic processes of life on Earth, which is the photosynthesis of plants. By the march of the plants from water, carbon dioxide, and other substances (nutrients) special form primary and stock substance of their bodies, which are then a source of food (material and energy) for other organisms. Light are bound not only plants but also animals. Some are active during the day and others at night. Solar radiation is a source of danger for living organisms. Ultraviolet radiation, which is usually collected in the upper atmosphere is life dangerous. [14]

It is limited photosynthesis and can damage the skin. Similarly, X-rays (X-ray), gamma rays and cosmic rays are dangerous to life. [14]

Important abiotic factors are including **pressure and flow**. Organisms living on the land are adapted to relatively stable **atmospheric pressure.** [15]

The pressure varies with changes in weather and altitude. With increasing altitude, the atmospheric pressure decreases. Far more is at a certain pressure-dependent marine organisms. If the mass of one liter of water equals 1 kg, then one dm^3 at 1 m below the surface treated with 10 kg at a depth of 10 m for 100 kg and 100 m below the water column already weighs 1000 kg. Deep-sea organisms living in the depths of over 10 km have to bear enormous pressures (at a depth of 10 km acting pressure corresponding to 10 000 kg). Such organisms, however, did not survive the shallows, where the water pressure is far less. [17]

Water or air they are almost never at rest. The flow is characteristic for them. Many species of animals and plants are adapted to the shape of the body to life in a powerful flow, others are adapted to conditions in a quiet environment. For many plant species, the flow of air (wind) need to spread their seeds or spores. Seeds of other species are distributed by water.

2.1.2 Chemical Environmental Factors

The life was probably arosen from the seas and all major physiological functions of organisms are tied to the **aquatic environment.** Water in varying amounts include any cells, tissues and organs. The organisms are different in relationship to the presence of water outdoors. There are recognized the plants xerophilic, wetlands and water. The absence of water or moisture could not survive amphibians, who lay their eggs into the water where they evolve and their larvae. On the contrary, many reptiles require for life rather dry conditions. Water is the life of organisms important factor also in the form of precipitation and humidity.

For most plants and animals is needed a constant supply of oxygen. The **oxygen** in Earth's atmosphere began to create probably carbon dioxide as a byproduct of photosynthesis primary organisms have about 2 billion years. Levels in the atmosphere for a long time is very stable and is thus one of the basic chemical substances that are necessary for life. [17]

The plants get carbon for the construction of their bodies from the carbon dioxide, which is also a fixed part of the atmosphere. Without his presence would not plant production on which they are dependent animals - herbivores and the whole chain of other organisms. [14]

In the soil and the water is present a number of **salts.** Their content can vary significantly. On their concentration depend on a variety of organisms. Salinity is also an important environmental factor. In many microorganisms is an important environmental factor on the acidity or pH, which decides on the presence or absence. Acidity or alkalinity is necessary or limiting factor especially in water and soil. Important chemicals especially for plants, fungi and bacteria are also a variety of nutrients. Are the most simple, water-soluble nitrogen-containing compounds, phosphorus, sulfur, potassium and other so called **biogenic elements** - elements, which forms the body of organisms. [17]

According to the nutrient content, the soil, water and other substrates from which organisms derive nutrients, can be divided to poor - oligotrophic, medium enriched - and mesotrophic nutrient-rich - eutrophic. The chemical agents is also being substances, which occur naturally in the environment, or are present in lower concentrations, or ratios, and in other forms. [14]

These substances are then deemed harmful pollutants. Many of these organisms are very sensitive to pollutants and react to them. Reaction may be e.g. escape from exposure, but also poisoning or death. For pollutants can be regarded as toxic substance (a compound of certain metals - mercury, cadmium, lead). Too basic or acidic (sulfur dioxide from coal combustion, which is involved significantly in causing acid rain), the dust that clogs the vents, and in greater amounts can limit the breathing of plants. [17]

2.2 Biotic Environmental Factors

For biotic impacts we can consider the action of organisms to one another. Direct biotic effect presents the bond of two (or more) species of organisms to one another. This is for example the presence of parasites (parasites) in the body of the host or prey and predator relationship. Indirect biotic influence is the relationship, when the organisms interact each other and changes abiotic or direct biotic factors. These example is the shading of plants growing in the undergrowth crowns of tall trees or on competition, of the food of two different kinds of predators. [15, 17]

In specific relationships with environmental conditions and other living organisms enter each particular **individual** or **group of individuals.** Individuals, who have identical genetic makeup and thus the body composition, metabolic pathways, the same rights to food and shelter, which is a common ecological niche (habitat) and propagated give rise to fertile offspring, are **members of one species.** [1]

Some species are related you have common ancestors or are a developmentally very far. There is always a way of life for all individuals of a species typical. Type can be simply defined as a set themselves also similar subjects who this their similarity (physical and metabolic) transmitted from generation to generation. [16]

Each part of the country, if left autonomous development, subjects to change. These changes in communities over time are called **succession**. A subsequent series of successional changes creates successional series (the principle of succession). [14]

A distinction is made [17]:

- **primary succession** - occurs in places, where there were previously no plants. E.g. addressed to the dunes, abandoned fields, a pond and the burned forest. They begin to discover bacteria, fungi, mosses, lichens, and the like.
- **secondary succession** - where already some plants discovered. Grass and herbaceous vegetation turns scrub, possibly forests.

Similarly, during the succession of plant communities change, there is also a change animal communities. These changes are compared with changes in vegetation less noticeable. The final stage of succession is to create a balanced community (biota) with the abiotic (non-living) environment. This steady state is maintained as long as will not change the critical factors of the environment. [16]

Relationships between organisms can be divided into two basic types. These are, first, the relationship between individuals of the same species **- intraspecific** and between individuals of different species - **between species.** [14]

The basic relationship is competition. It is a relationship where individuals compete for the same or different kind of basic conditions of life. "*To rival*" is possible for space, light, water, food and other environmental factors. A typical example of competition within a species is competition for a partner for reproduction and territory. Plants can compete roots or branches shadowing. Competition can lead to complete suppression of other species, or steady state is achieved and competing species can exist side by side **(coexistence).** [14]

Among alien species is very common relationship **predation**. It is a bond, in which one organism is food for another. Predator is one, who is a second living organisms. Predators may herbivore and carnivore. Carnivores in obtaining food for prey attack and kill. Herbivores feed by parts of the other organism, while not have much influenced on its viability. [15]

Two different organisms may also feed upon the carcasses or products of the metabolism of other species. It is parasitism. **Parasitism** is often regarded as a special type of predation. Parasite and its holder are together in far closer bond than predator and prey. Right parasite is always heterotrophic organism since gaining nutrients other than its own mechanism of photosynthesis. [14]

Some plants such as mistletoe are considered to half-parasites. For his life from the host need only some minerals dissolved in water. Typical parasites are organisms that live inside the body of the host (endoparasites) or on the surface (ectoparasites) feeding with body fluids, tissues, body parts or body coverage (feathers, hairs, scales). Some organisms are parasites at a certain stage of development. Larvae, fleas live freely and feed on organic residues in dust and dirt. [16]

Adult fleas parasitic on humans and animals. Some parasites can also have a number of hosts. Several parasites, which feed primarily by blood and body fluids, the sucking may transmit dangerous diseases. In the Middle Ages it was such fleas that transmitted plague bacteria. Today in our country are among the carriers of dangerous diseases ticks. When sucking blood can pass viruses causing meningitis or Lyme disease bacteria. [17]

Some types of organisms can live together and reap the benefits that they bring cohabitation. Mutual benefits are reflected in the ease of obtaining food, better growth, survival or success in reproduction. This type of relationship is called **mutualism** and **symbiosis** is the most common example - solid coexistence of two organisms. [16]

Some species of green algae and fungi grow through each other and form lichens. Bond is so strong that lichens are normally considered separate organisms and described as a separate species. Are mutually beneficial coexistence of intestinal microorganisms and hosts. These bonds are known in ruminants or by termites. In both cases the host is a supplier of food and symbiotic micro breaking down cellulose. He himself is the living and at the same time makes the nutrients your host. [14]

Looser bond presents interplay between insects and some bird species and flowering plants - **protocooperation.** Both parties cooperation of benefit. Pollinators feed on the juices of various floral and pollen while helping pollination. Relations pollinators of flowering plants and in many cases so perfect that pollination can perform only certain insects with special adapted (long proboscis, hair, cups on the limbs, etc.). [17]

Some organisms together even cooperate directly (cooperate). A classic example is the **cooperation** of the South African Honeyguide bird that feeds wax, bee larvae and honey. Alone he is not able to break the nests of wild bees. He attention therefore with its behavior baboons, and mustelidae and attracts them to the nests of bees. They destroy the nests of bees and honey smashing and feed on insects and along with them honeyguides. In areas where the nest of bees collected natives honeyguide cooperates with people. [14]

The exceptional position among organisms have man. **Man takes and collects** a variety of animal and plant species whose populations living in natural and semi-natural conditions (game animals in the forest, fish in the seas and oceans, oysters in shallow seas, etc.). [14]

Interest of treasurer or the hunter is the **maximum yield** for the current maximum possible recovery of the population as possible as long as possible. The maximum yield can be achieved, of course, if it is caught or harvested the entire population of the desired/ required organism. The full collection can not be performed only once, because then it does not remain any individual for further propagation. [14]

Ecological research has shown that the best answer is to get at least some use of the population size and its growth. Many species tested reproduction is fastest when the population density of the minimum and maximum, or about the mean. Then it is also the highest increase and therefore that the individuals of the population is very little competition. At high densities, the competition is great and the gain is smaller subjects. When fishing from a small population may decrease the number of individuals below a critical level and the time for its demise. [17]

2.3 Time

All abiotic physical, chemical and biotic impacts not carried still the same force and are not tied to a single moment. The circulation of the Earth around the Sun and the rotation of the planet on its axis are affecting almost all living and nonliving systems for hundreds of millions of years. Adjustment of organisms and timing of various manifestations and their compliance with planetary time is referred to as the **biological clock.** The main cycles are cycles of 24 hours, or daily cycles and seasonal cycles. If the answer is any periodic change in behavior or the metabolism of any organism regular natural cycle changes, then we talk about **biological rhythms.** [11]

The daily cycle is typical for flowering council of plants. Flowers open during the day in order to pollinators transfer pollen and close them at night. Plants and animals, but not recognized as the difference between day and night, but also the length of the solar day. Many higher plants blooms for a long day, and others again for a short day. [11]

Seasonal cycles are four seasons and also the rainy season and dry. Corresponding rhythm in the life of organisms may be moving birds from our latitudes south in the fall and return to the beginning of spring. Another type of rhythm may be migration of herds of herbivores in African savannas after the rainy season and the way back before the start of the dry season. A similar rhythm is observed also in animals that band members sleep unfavorable winter.

Responsiveness to the regular cycle of sun exposure (photoperiods) may not be the only example of rhythm in nature. Marine animals and plants that live in the intertidal zone of the coast very sensitive for example **the substitution tide.** [1]

2.4 Ecological Valence and Tolerance

Incidence and successful survival of organisms in nature depends on a set of external conditions. Each organism has its specific boundaries, which is limited by the **tolerance** of the action of various environmental factors environment. The range of intensity or concentration of any one factor in an environment where the organism adapts called **ecological valence.** [18]

Limits of tolerance are defined on the one hand, the minimum and on the other, the maximum value of the ecological factors (Fig. 13). The mean values of intensity or concentration factor indicate the **ecological optimum** for growth, development and reproduction of the organism. The range of ecological valence for each factor varies by a large variety of organisms. Some organisms tolerate a wide range of solar irradiation, or can live in the soil with very low levels of water, optionally in the wet soil. [18]

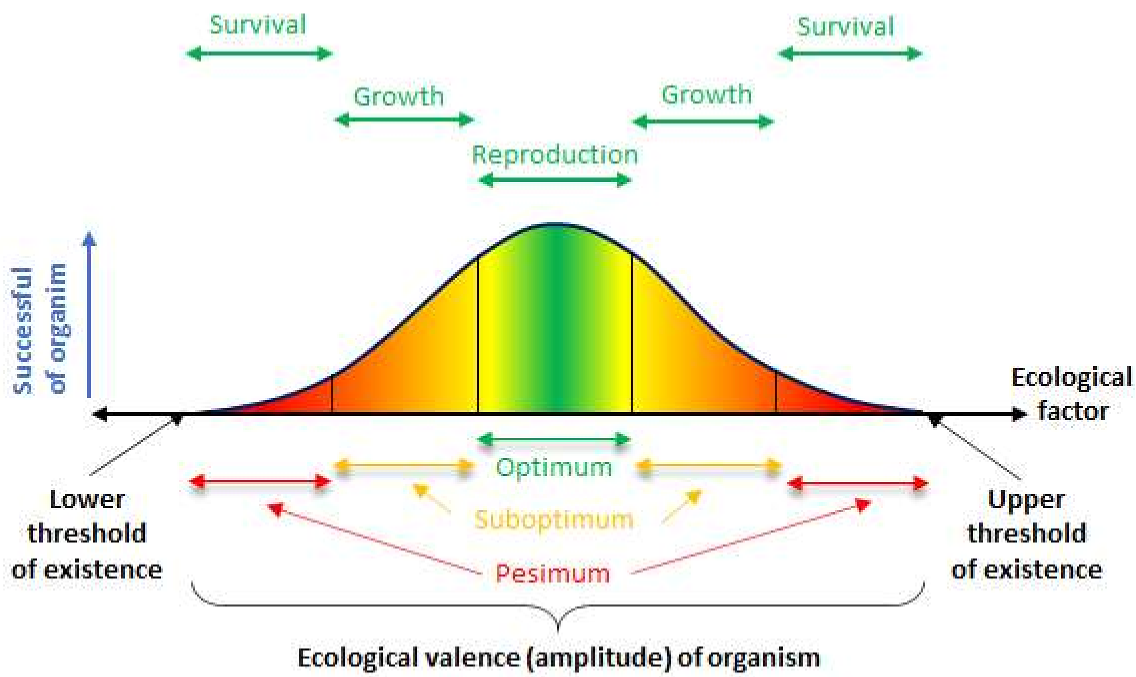


Fig. 13 Environmental valencia organisms [11]

Other organisms are probably quite sensitive to variations in environmental factors in the environment, and therefore have narrow ecological amplitude. In general, one can identify the species stenovalent and euryvalent. While in the first case, organisms tolerate little variation in ecological environmental factors, the latter are also tolerant to the major changes. Stenovalent species occur less frequently, are rare, they live at special stations and also tend to have smaller surface extension - **area.** [18]

Euryvalent species are widely adaptable habitat conditions, often reach high population density and occupy a larger area. According to the tolerance of organisms can each ecological factor (environment) to add a couple of names. For example, according to temperature tolerance knows stenotherm or eurytherm organisms. Stenotherm species are active only in a narrow range of temperatures, and may be of cold body with a temperature optimum at low temperatures or in the thermophile temperature optimum at high temperatures. Eurytherm species of tolerate in a wider temperature range. [18]

According to habitat we know types stenotopic and eurytopic ones. Stenotopic organisms living on one or only a few stations and are relatively little spread, while eurytopic colonize different habitats and are much more widespread.

Each organism is affected to the headquarters of the factor, which acts on it at the same time. Environmental factors that affect the extent of the limits to the survival of individuals especially critical and called the limiting factor. The occurrence of the species at the positions taken by majority precisely this factor, which has been operating outside the bounds of the adaptability of the species. [1]

For example, in our climatic conditions in the terrestrial communities very often the limiting factor in the summer is the water in the soil. Its deficiency in the soil causes of species extinction water-intensive, although other conditions (sunlight, minerals) are optimal for organisms. Second, such as aqueous limits the development of aquatic organisms of oxygen, the concentration of which fluctuates in time and space. For example, high summer temperatures, the oxygen concentration in the surface waters decreases due to the reduced solubility. [11]

Similarly, the limiting factor is the presence of some biogenic elements needed for plant growth. This has caught Act minima (J. Liebig, 1840), which states that plant growth is limited by the element that is the minimum. Relations organisms (or communities) are formed in relation to the environment in certain bonds. Organisms from the environment need materials and energy for their metabolism and growth, the environment must degrade unnecessary products of metabolism, to create conditions for copying processes, the spread of offspring and their own way and provide a degree of protection of the body against stress situations. These relationships are the result of millions of years lasting adaptations of organisms to their environment and reflection is rooted in the phylogeny of organisms and genetically fixed. Therefore, addressing environmental protection is by no means a simple matter. [18]

3 SOURCE OF ENERGY AND OF THE NATURE

Animate and inanimate component of nature is closely tied. Chemical components of the environment will pass through their typical ways to organisms and organisms are returned to the environment. If you examine these paths are conjoined each stop and transformation finds the cycle of individual substances in nature. Within the cycle varies specific form of the substance, but the total amount remaining at the end and beginning still the same. Therefore, refers to the cycle (cycle) of the substance and not to that of the flow of energy - the part is always converted to heat which is radiated into space. Substance cycles not carried quite regularly. Organic matter can accumulate somewhere, cycling temporarily slowed or stopped. Part of the cycle, which takes place in living organisms is quick, part of inanimate nature is slow and represents a reservoir of substances for further use. [19]

The human intervents into all of the cycles of production of various substances (fertilizers, heavy metals, plastics, etc.). These substances directly enter into the cycle and accumulate in organisms and in inanimate nature and have negatively affected because the majority are toxic. [1]

3.1 Energy

Energy naturally arises either extinguished. It can only be converted from one form to another. Whatever the conversion of energy from one type to the other is always a certain part change into heat (so-called residual or waste heat), which can not be used longer. This means that no transmission is not 100 % efficient. [3]

Under these rules, the hidden energy in chemical bonds of carbon and coal for combustion in thermal power released, converted to thermal energy, which the electrical energy, allowing the emission of light in the lamp (1-st law of thermodynamics). However, none of transformation do not run without the losses. Always heat released into the environment, which cannot be longer converted. Heat escapes from the incineration with heat turbines friction, the conversion of voltage transformer, heat also publishes lit bulb (2nd law of thermodynamics). [19]

Similar transformations are taking place and naturally, since all the manifestations of life needed some energy.

The Primary Source of Energy on Earth is the Sun. Solar radiation, especially visible light (partly ultraviolet and infrared radiation) passes through the Earth's surface and is only available to green plants. [3]

Power flows atmosphere, soil and ecosystems are shown in Fig. 14 [19]. Even though the amount of energy that reaches the earth's surface is huge, for own photosynthesis is usable in the plurality of less than 1 % of this energy.

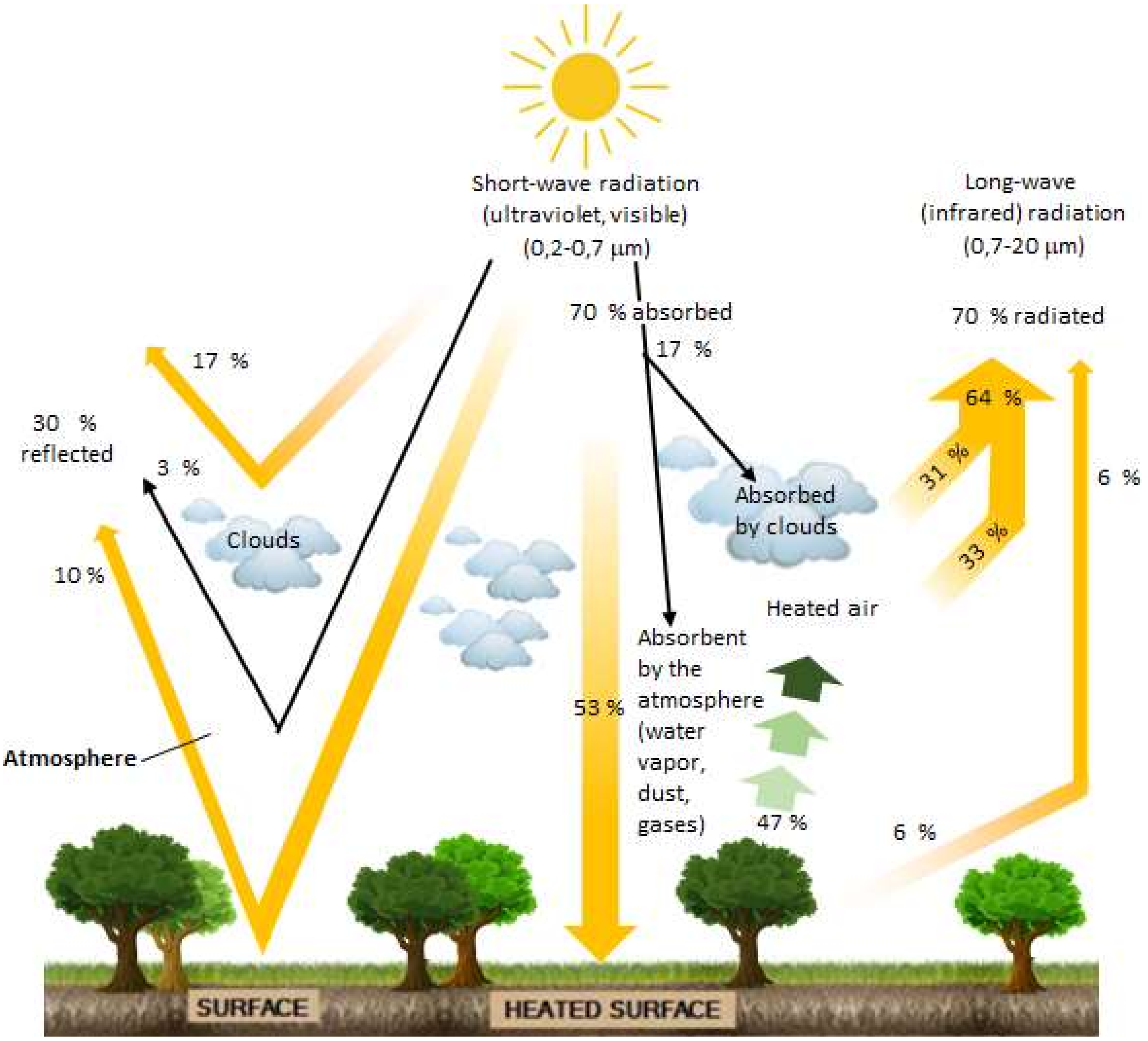


Fig. 14 Flows of energy [19]

3.2 Mass

The material also applies fundamental physical law - **the law of conservation of mass**. Any matter can not, under normal conditions create out of nothing, or it can not be consumed. Substances alter the physical state of the compound are reacted in chemical reactions, the solid crystals are dissolved in solvents. The material passes from one form to another and when these changes not decrease nor increase (the laws of physics, relativity, however, shows that mass and energy are linked together so it says on the laws of conservation of mass and energy of the law of equivalence of mass and energy is expressed known Einstein's formula $E = m.\ c^2$). Substance is present in nature in the form of atoms and molecules of various substances. Simple matter - inorganic, to the most complex substances - organic. [11]

3.3 Cycle in the Nature

None substance (compound, element) does not occur on the surface of the Earth only in one place, in one form, and unaffected by other substances or organisms. Water currents in the seas and rivers carry at all times large amounts of substances. A similar role is played by the wind in the atmosphere. In the course of rock-forming processes are changing and moving across the land. All these processes ensure the movement of various substances on earth, and the availability of nutrients in the form of organisms. Since these processes jointly participate in biological, chemical and geological happens, it is called the **cycle of matter on Earth biogeochemical cycles.** [1, 11]

Although the living organisms are composed of a number of components (usually 30 to 40), the bulk of the organisms is also made of several **prime - biogenic elements**. These are: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S) and phosphorus (P). The life are also needed **in smaller quantities additional biogenic elements** such as: Iron (Fe), sodium (Na), potassium (K), calcium (Ca), chlorine (C) and more. The slight - trace amount necessary elements such as iodine (I), selenium (Se), zinc (Zn), copper (Cu), cobalt (Co), molybdenum (Mo), vanadium (V), and the like. All of these elements (also with other features not listed here) is the cycle prerequisite for the existence of life. The movement of the water, air, rocks and organisms knows no natural or political boundaries. Cycling of elements essential for life can not describe the level of field, forest, county or state. To understand the need for a global - planetary view. [3]

3.3.1 The Rock Cycle

The oldest, that is the most original of the cycle is called **rock cycle** (Fig. 15). It is "*driven*" by large forces and is managed by complex mechanisms, which are the activity of the Earth's interior (core and shell) and the subsequent movement of tectonic and climatic influences. [20]

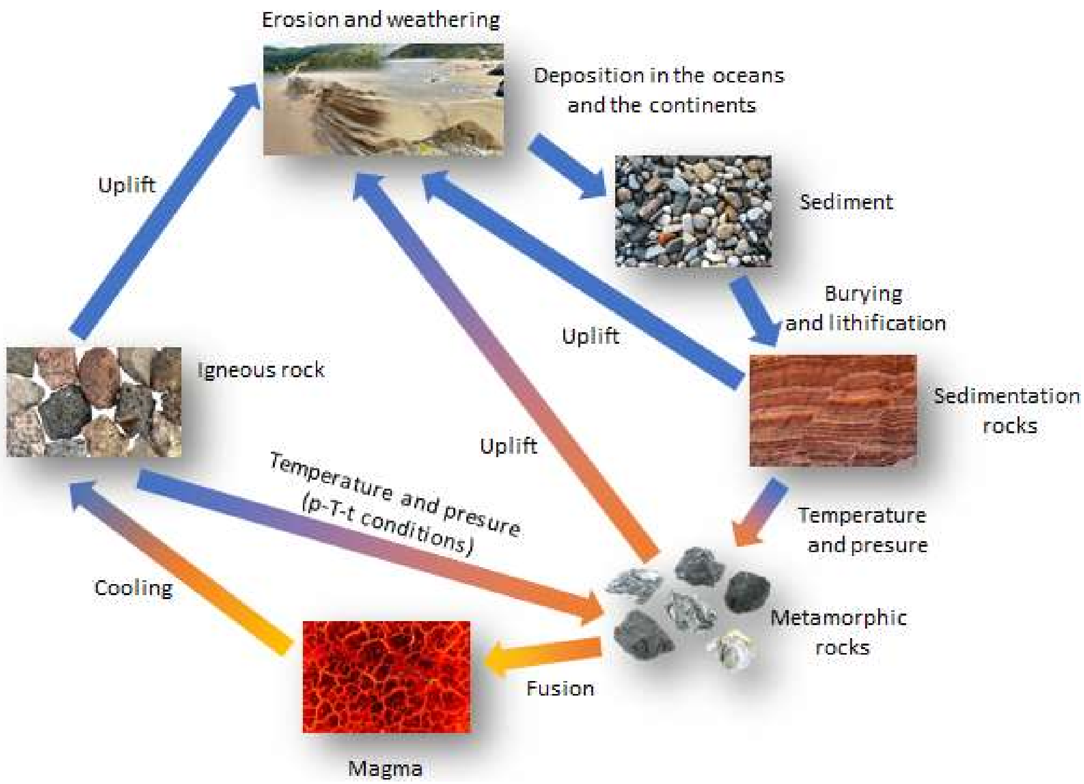


Fig. 15 The basic geological (rock) cycle

The cycle of matter in the rock cycle and the process of deformation of rock is many times longer than the length of a person's life, and also longer than the life of the last few generations, where one could explore rock-forming processes using modern scientific methods. The cycle of substances in rocks is governed by the so-called **geological time**. A slip gauge there are no hours, days and years, but millions to hundreds of millions of years. [20]

3.3.2 The Cycle of Water (H_2O)

On the rock cycle is closely linked cycle of another substance, which has always been and for life on Earth is inevitable and it is the water (H_2O). You probably already during the cooling of the earth's surface from some rocks loosened bound water, which gradually precipitated on the surface of the planet and thus created the seas, oceans, lakes and rivers. Water has become part of the Earth's atmosphere, land, and created the polar sea ice and underground reservoirs. Water mantle (hydrosphere) therefore arose as a result of degassing of the Earth's interior. [21]

For the purposes of ongoing changes in the physical state of water and its transformation from one stage to the other with energy mainly sun. The existence of the world's oceans and the water cycle ensure the relative duration of the global climate and necessary to sustain life on our planet. The water cycle (Fig. 16) can be divided into several parts. The main reservoir is the world's seas and oceans. In them there are about 97 % of the total volume of water on the surface. The remaining 3 % are found in glaciers, groundwater, soil water, rivers and lakes (surface fresh water), in the atmosphere and ultimately in living organisms. [21]

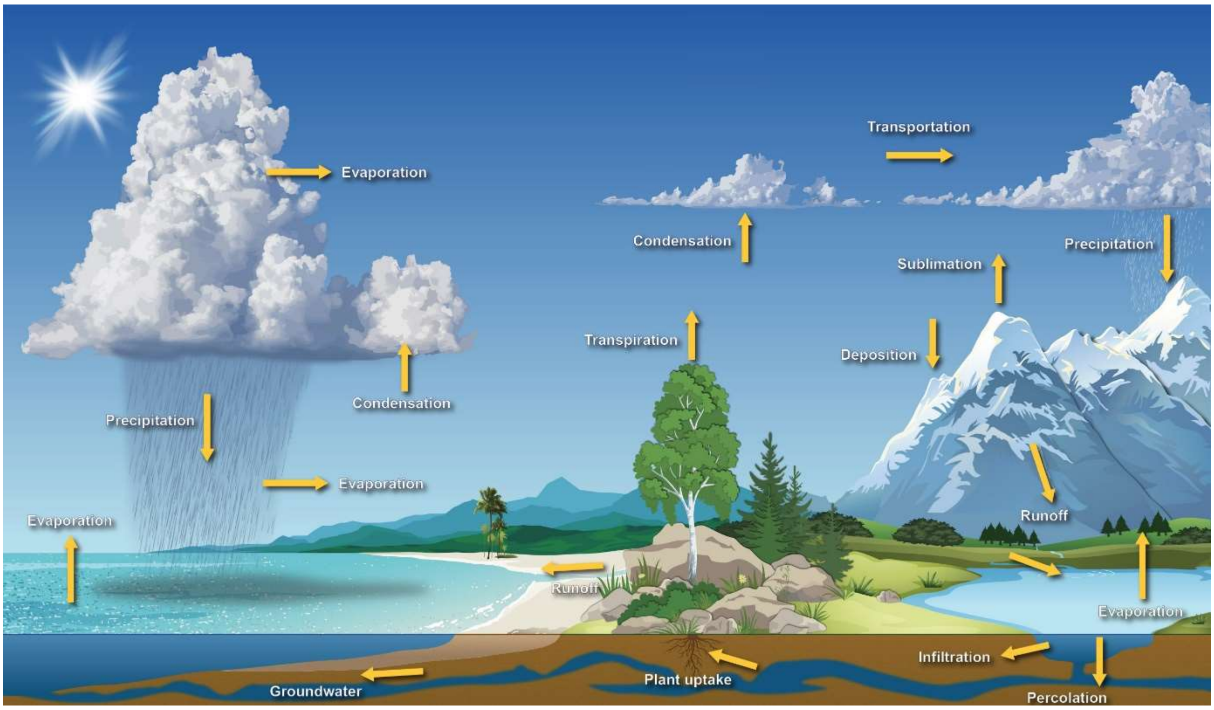


Fig. 16 The cycle of water (H_2O) [22]

Along with the water is circulating on the surface not only a wide range of dissolved and suspended solids as well as heat. Thermal differences between day and night, and especially in different seasons, they are the main driver of terrestrial climate. On the water cycle, the rock cycle, the processes in the atmosphere and in the last decades and the human activities are linked the of cycles other major biogenic elements - carbon (C), nitrogen (N), sulfur (S) and phosphorus (P). [21]

3.3.3 The Carbon Cycle (C)

Carbon is a basic biogenic element. It is the most abundant element of living matter. From an environmental point of view is a very important component. The cycle is one of the simplest (Fig. 17). Part of the carbon is in surface and groundwater as HCO_{3^-} anion. Under natural biochemical cycles, the carbon present mainly in the form of carbon dioxide (CO_2), that together with oxygen. The largest part of the carbon on Earth is accumulated in rocks containing $CaCO_3$ and $MgCO_3$. [23]

Carbon is the basic building block of all organic substances. Its main source is the atmosphere. Through photosynthesis passes into biomass as organic carbon $(CH_2O)_n$. Crucially ratio of CO_2 in the atmosphere of CO_2 dissolved in the water. The exchange between these environments is happening in diffusion and water gets into the precipitation. Is dissolved in water the bicarbonate, carbonate. The carbon is bound in the mineral form of the insoluble carbonates (Ca, Mg), respectively. in containers organisms. Microorganisms consume CO_2, thereby slightly increasing the pH and precipitate the carbonates, which are stored in boxes elements, corals, molluscs. [23]

Organic carbon is fixed organisms over millions of years of biochemical reactions transforming fossil fuels - oil (hydrocarbons), coal (petroleum hydrocarbons degrade microorganisms in peat bogs formed and coal). [23]

Industrial activity, the fuel from those fuels transported into a large number of different compounds containing halogens, oxygen, sulfur, nitrogen and phosphorus. These substances in terms of proportion by weight not constitute a significant proportion of the total carbon, however, cause a serious problem due to toxicity. [1]

An important feature of photosynthetic conversion of inorganic carbon to organic, the accumulation of solar energy to be recovered for oxidative combustion of fossil fuels. Photosynthesis of algae is another way of transmission of atmospheric CO_2 to $CaCO_3$, forming a large part of sedimentary rocks. [23]

In the result of reducing the dissolved CO_2 with a consequent increase in pH and precipitation of calcium carbonate. Returns to the atmosphere of CO_2 from biomass (respiration) and oil.

Hydrocarbons contained in oil and oil products, or in environmental pollutants can be degraded by microorganisms recovered. The biodegradation is the primary treatment of various wastes. [11]

Carbon enters the trophic structure of the community at the moment is a simple molecule binds CO_2 for photosynthesis. If the molecule is incorporated in the primary production may be as part of sugars, fats, proteins or cellulose to be used to the consumption of other trophic levels. [23]

It moves like energy, i.e. gradually consumed, assimilated, excluded and optionally incorporated into the secondary production. Once the energy-rich molecule containing carbon is used as a source to provide power for operation, energy is released as heat and carbon as CO_2 excreted into the atmosphere. [11]

At this point strong link is up energy and carbon. Carbon dioxide is exhaled organisms in the decomposition of dead inorganic matter is returned to the circulation in the form of CO_2. The accumulation of large amounts of organic residues can slow the carbon cycle - creating new organic substances (e.g. humus, which is important for maintaining soil fertility), in which decomposed processes run slowly. [23]

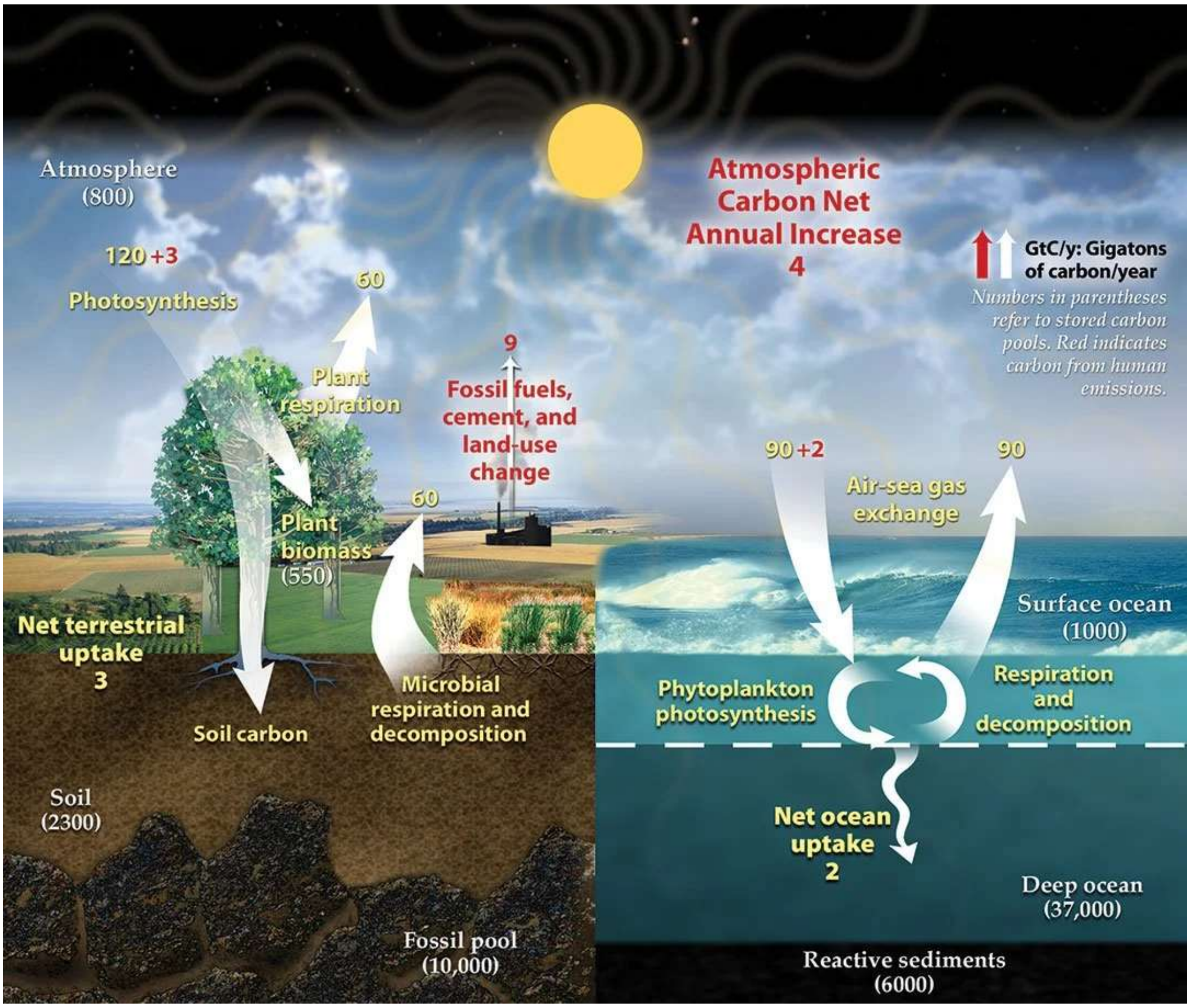


Fig. 17 The carbon cycle (C) [24]

When a chain of decomposition cannot work well (e.g. for lack of air, a very acid environment, and others), organic substances accumulate in the form of peat. Peatland carbon cycle is stagnation. [23]

The cycle may also stagnate the water when CO_2 accumulates in the form of $CaCO_3$ (e.g. chalk, limestone, coral). [1]

Steady-state CO_2 is disturbed by anthropogenic activities. In recent years, the amount of CO_2 increased industrial activity of man. Reduces the example of the area to the primary output, which is undermined by the ratio of photosynthesis and respiration at the expense of the photosynthesis, which increases atmospheric CO_2. [11]

Interventions in forest stands, there is a reduction of humus and hence stocks therein carbon content. Results of the rapid decomposition of humus is also an increase in the CO_2 content of the atmosphere. [11]

Constantly increasing levels of CO_2 in the atmosphere leads to the manifestation of the so-called greenhouse effect. Carbon dioxide, water vapor over the second largest of greenhouse gases. Carbon millions of years stored as fossil fuels like coal, oil or natural gas. Carbon cycle is called the exchange of carbon between the atmosphere, plants, animals, land and oceans. In nature, this exchange takes place more or less naturally. Around the end of the 18-th century, but the amount of carbon dioxide in the atmosphere began to increase. The main cause is the burning of fossil fuels. Important role in the disruption of the carbon cycle also played a massive felling and burning of forests. The atmosphere is so given the amount of carbon that was stored in forests and their loss is affecting its absorption. [23]

If a man is cutting down trees and burn fossil fuels, it is causing an increase in the natural level of carbon in the atmosphere and is increasing the greenhouse effect. Extraction of fossil fuels and their combustion are carbon stored underground gets to the carbon cycle as a part of the atoms absorb trees, plants, soil and oceans. Due to upset the balance of the carbon cycle but the greater part up in the atmosphere. On the other hand, begin the processes of production so called biochar (charcoal equivalent) of wood and biowaste, followed by application of biochar to the soil. Biochar in the soil breaks down very slowly (for hundreds of years), and carbon is deposited in this way (i.e. Sequestered) long in the soil, reducing the concentration of CO_2 in the atmosphere. [23]

Biochar in soil also enhances the quality of the soil, improves soil fertility, reducing the need for artificial fertilizers, soil fertilization and further reduce emissions of the greenhouse gas N_2O from soil. These are important secondary contributions biochar application to soil to reduce greenhouse gas emissions. [1]

The main greenhouse gases are [23]:

- carbon dioxide (CO_2) - 55 %,
- chlorine-fluorine hydrogen (ClC CFC) - 23 %,
- methane (CH_4) - 15 %,
- nitrous oxide (N_2O) - 7 %.

Increasing emissions of these gases is causing increased global warming of the Earth.

3.3.4 The Cycle of Oxygen (O_2)

Oxygen is a colorless gas essential to life on Earth. It serves to provide biogenic processes and combustion. Oxygen cycle is closely linked to the cyclic circulation of other substances, but especially the carbon cycle. [25]

The atmospheric oxygen (O_2) is currently organic. The initial composition of the gaseous envelope of the Earth contained water vapor, toxic gases and the Earth's surface turned UV - radiation. O_2 was the first atmospheric origin after they have been created cyanobacteria originated O_2 organic origin.

In an atmosphere of oxygen is represented in the form of molecular oxygen (20,943 vol. %) and carbon dioxide (0,0314 vol. %), water vapour and ozone (0,000002 to 0,000007 % vol.). Particularly important is the presence of ozone in the atmosphere because it absorbs ultra-violet solar radiation in the range 220 – 330 nm, which damages the tissues of living organisms. [25]

Oxygen was started to leak into the atmosphere only after the ultraviolet radiation penetrate the Earth which caused the dissociation of the water vapor in the upper atmosphere and result in oxygen. After the establishment of simple organisms, oxygen (O_2) increase was greater in the volume of ozone (O_3). Thus was created the ozone layer and the Earth began to evolve life. The first anaerobic organisms had to adapt to the climate of oxygen. She developed photosynthesis and thereby dramatically increase the amount of oxygen in the atmosphere. They began to evolve organisms capable of respiration. Most oxygen in the currently released algae and photosynthetic plants. Part of the oxygen is bound in the carbonate sediments of the seas and oceans. The balance of O_2 in the atmosphere is maintained in that the organic oxygen is stoichiometric equal to the amount of O_2 produced. The reoxidation occurs during the burning process. The only way to get O_2, is to determine the necessary amount of carbon in the ecosystem, namely [25]:

- **short term** - in lignified organs (e.g. tree trunks, etc.)
- **long-term** - in an anaerobic environment (e.g. peat, humus, oil, coal, etc.).

The cycle concludes oxygen **photosynthesis** of plants, as the biggest story reversible return oxygen back into the atmosphere (Fig. 18).

Photosynthesis (from Greece. Photos = light, Synthesis = binding) is a biochemical process of capturing solar energy and its use for the fixation of carbon dioxide in green plants and some prokaryotes to form carbohydrates. It is a kind of assimilation of carbon dioxide. During photosynthesis in the cells of plants, algae and some prokaryotes, changes the received light radiation energy to the energy of the chemical bond and the resulting organic substances from inorganic materials. Organisms that provide their energy needs through photosynthesis are called autotrophic respectively photo-autotrophic one. [25]

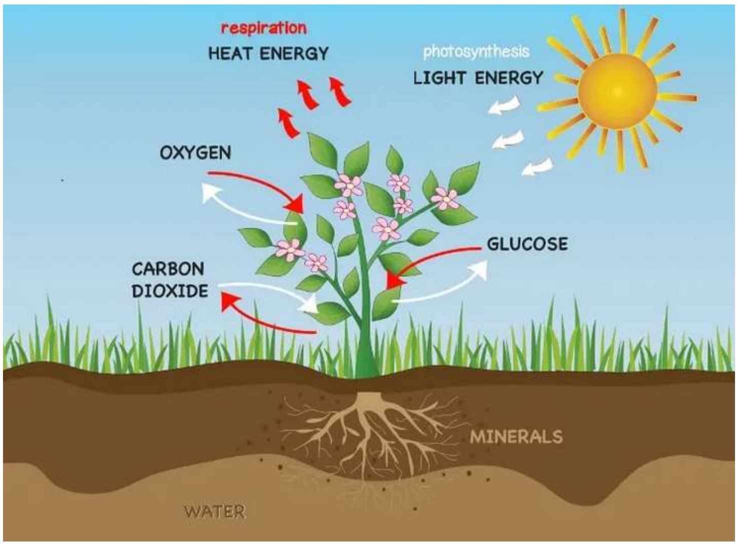


Fig. 18 Reversible O_2 back into the atmosphere [26]

Photosynthesis is considered in terms of actual life, the most important process on Earth. During photosynthesis creates organic substances that consume in their diet heterotrophic organisms. Photosynthetic organisms fixed approximately 17,4 x 1010 tons of carbon by year. Parallel with the binding of CO_2 to the atmosphere releases oxygen in an amount of up to 5 x 1010 tons, thereby maintaining the life of the appropriate concentration in the air. [25]

Chemically, the photosynthesis expresses the general equation:

$$12\ H_2O + CO_2 \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6\ H_{12}\ O_6 + 6\ O_2 + 6\ H_2O \qquad (3.1)$$

In plants, photosynthesis take place in two phases [25]:

- **Light phase** - has been undergoing primary photosynthetic processes associated with income (absorption) and the conversion of light energy into chemical bonds.
- **The dark phase** - has been undergoing secondary biological processes associated with the fixation of carbon and conversion of inorganic carbon (CO_2) organic (carbo-hydrates).

Site of a 99,9 % by photosynthesis in plants is the leaf of a plant (Fig. 19).

The general dependence of utilization of incident (photosynthetic activity) radiation in photosynthesis plant is shown in Fig. 20.

If the light intensity will rise, will rise also the intensity of photosynthesis. Upon reaching socalled "*Light compensation point*" (Fig. 20, point B), there is a settlement with the consumption of O_2 breathing dispensing CO_2. Respiration and assimilation are balanced. [25]

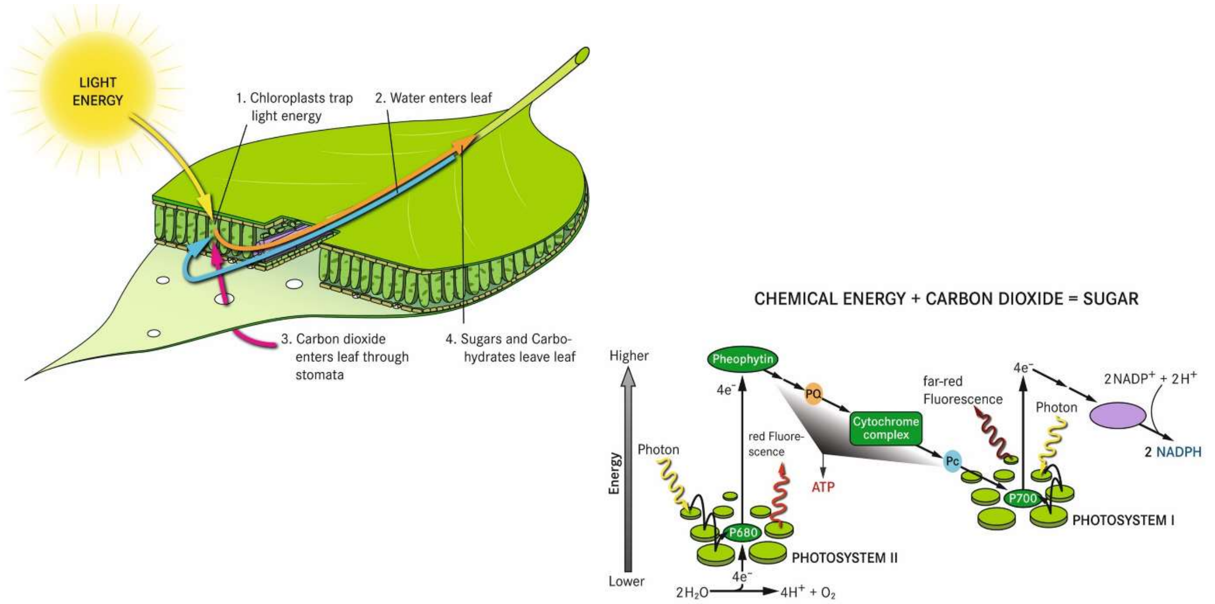


Fig. 19 Plant List - place during photosynthesis [27]

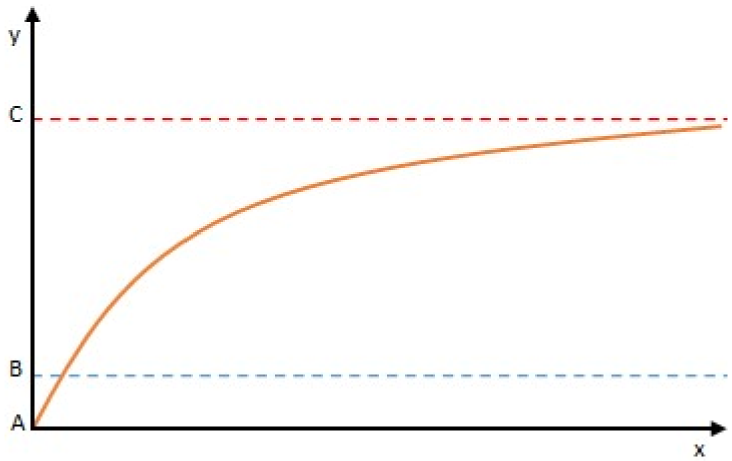


Fig. 20 Dependence of the intensity of photosynthesis in the supplied amount of light, A - in dark respiration (O_2 net income), B - light compensation point (respiration and assimilation are balanced), C - the maximum level photosynthesis

Initially, the relationship between the intensity of photosynthesis and growth light intensity linear (outside plant produces O_2 and CO_2 consumed. At higher increments of light radiation but begins to decrease and there is a state of "*saturation*". Once photosynthesis reaches the maximum value, the plant ceases to further increase the light intensity response. [25]

Light is the primary energy source for photosynthesis. What is important is the quality (color), intensity and duration of action. The organs of photosynthesis in the plant leaf absorbs up to 2 – 3 % of the light, the rest transmits or reflects only some green algae absorb up to 20 % of solar radiation such as Chlorella. [25]

Maximum absorption of light falls on wavelengths around 640 – 700 nm, the red light. Lists well absorbed blue light has a wavelength range 430 – 460 nm corresponding to the absorption of chlorophyll, photosynthetic pigments as the head. Other wavelengths plants can absorb through several additional dyes. Their representation in the leaves but is smaller and the efficiency of use of light absorbed in photosynthesis is lower. [25]

Carbon dioxide

The concentration of carbon dioxide (CO_2) in the current climate is 0,036 %. This component of the atmosphere is the basis of nutrition of the whole organic world. The amount in the atmosphere increases the production of bacterial decomposition of organic matter, respiration and combustion of fossil fuels. The higher concentration of CO_2 is a greater photosynthetic efficiency (especially in C_3 plants), but the acceleration of photosynthesis is often only temporary and due to other factors, which it is affected (e.g. the availability of minerals, especially nitrogen).

Water (H_2O) is very important for the life of photosynthetic organism, but also as an important electron donor during the photosynthetic reaction. Water comes from the oxygen that is released for photosynthesis. If the lack of water does not take photolysis of water, the plant closes the stomata and thus limited supply of CO_2. Does not take going photosynthesis, reducing the amount of ATP, the plant withers and later may die.

3.3.5 The Cycle of Nitrogen (N_2)

Nitrogen gas is **the most abundant element in the earth's atmosphere.** As release nitrogen (N_2) makes up more than ¾ (0,78 %) of the volume of all gases in the air. Also important are the other gases containing nitrogen although their quantity in the atmosphere is very small (nitrous oxide N_2O, carbon monoxide NO, nitrogen dioxide NO_2 and ammonia NH_3). Nitrogen is an important biogenic element is part of amino acids, proteins, nucleic acids (bearer of hereditary information). In rocks, the nitrogen does not occur in such an amount carbon (C). Only some minerals (nitrate) are rich in nitrogen. [30]

To carry nitrogen cycle especially so-called **nitrifying organisms**. They are capable of binding atmospheric nitrogen and transform it into soluble nitrogen compounds, which are acceptable as nutrients for autotrophic organisms (plants). They incorporate nitrogen between civil and stocks of the substance of their bodies. [30] From there, then it gets either nitrogen into other organisms (in the form of plant foods), or plants die bodies back into the environment - soil or water. Protein in the receiving environment as well as an animal metabolic waste (feces, urine, urea, uric acid). In the soil the nitrogen bound in the humus and can be released therefrom again, denitrification microorganisms to air. Thus, the cycle closes. Schematic nitrogen cycle is shown in Fig. 21.

The production of crude protein contributes a certain extent, a natural **volcanic activity.**

Nitrogen cycle and its compounds can be disturbed man primarily a disproportionate application of **nitrogen fertilizers**, both industrial (nitrate) as well from cattle. Fertilizers are rinsed out of the soil horizons into streams, rivers and lakes, which are the cause of abnormal increasing the nutrient content - eutrophication. Serious disturbance of the nitrogen cycle **combustion processes**. Nitrogen is at normal temperature low reactive. At higher temperatures (over 1200 °C) combines with oxygen to form nitrogen. The organic bound nitrogen in fuels and waste, is above about 500 °C, in part oxidised to nitrogen oxides (NO and NO_2), and part of nitrogen (about 60 %) is released with the form molecular nitrogen (N_2). The combustion process creates large quantities of N_2O. Some of these gases may impact on the strengthening of the greenhouse effect, or the erosion of the ozone layer. In the reactions of nitrogen oxides with water yields acid and these are one of the causes of acid rain. [30]

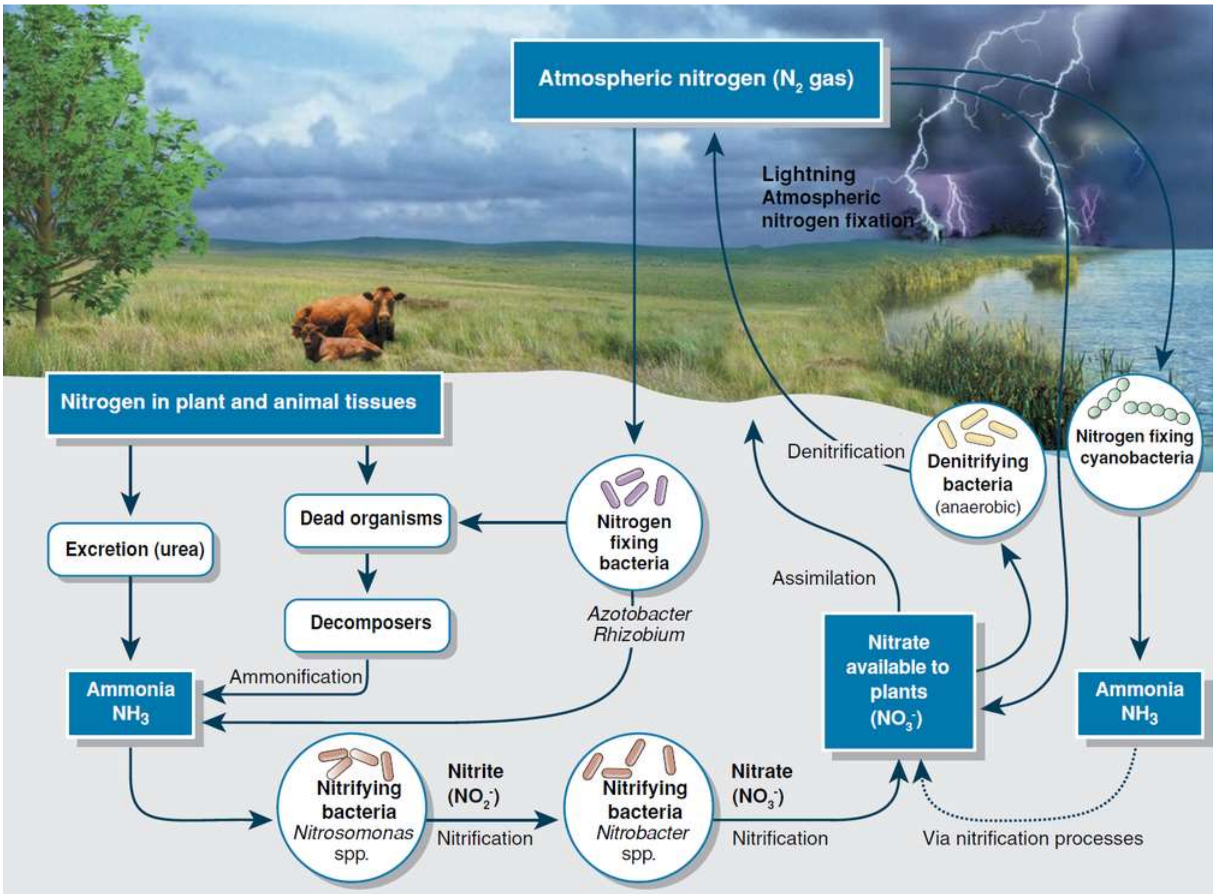


Fig. 21 The cycle of nitrogen (N_2) [29]

3.3.6 The Cycle of Sulfur (S)

Sulfur in the soil comes from the decay of dead bodies of rock or plant. Animal carcasses containing little sulfur compounds. Similar to the nitrogen in the sulfur cycle, play an important role of micro-organisms. The end products of microbial activity, which is generally carried out in aqueous medium or in wetlands and swamps and to a limited extent, in soil, is hydrogen sulfide (H_2S) [30]. Hydrogen sulfide is the result of degradation processes without oxygen, which run mainly in swamps and wetlands. It is easily identified by a characteristic sulfur odor. The microorganisms in the ocean creating more complex compounds - dimethyl CH_3SCH_3. Both substances in the atmosphere is oxidized and produces sulfur dioxide (SO_2). After a further oxidation reactions in the atmosphere as part of the rainfall (i.e. Acid rain) sulfur gets back to land, where together with other water soluble sulfate drawn into the circulation and becomes part of the mineral nutrition of plants. Sulfur cycle is schematically shown in Fig. 22. [30]

Paradoxically, this natural sulfur content in the bodies of plants and animals is one of the main causes of abnormal enrichment of the atmosphere with carbon dioxide. Fossil fuels (e.g. coal and oil), which are nothing more than "*dead*" biomass, always contain certain amounts of sulfur. By burning these fuels, especially in the last two centuries in the form of sulfur dioxide gets into the planetary cycle of sulfur, which is accumulated over millions and perhaps tens of millions of years during the growth of prehistoric plants and stored along with their unaltered residues in the swamps where no air and under great pressure carbonized. [30]

The amount of sulfur from fossil fuel combustion is now even higher than the natural leakage of carbon dioxide from active volcanoes and hot mineral springs. [30]

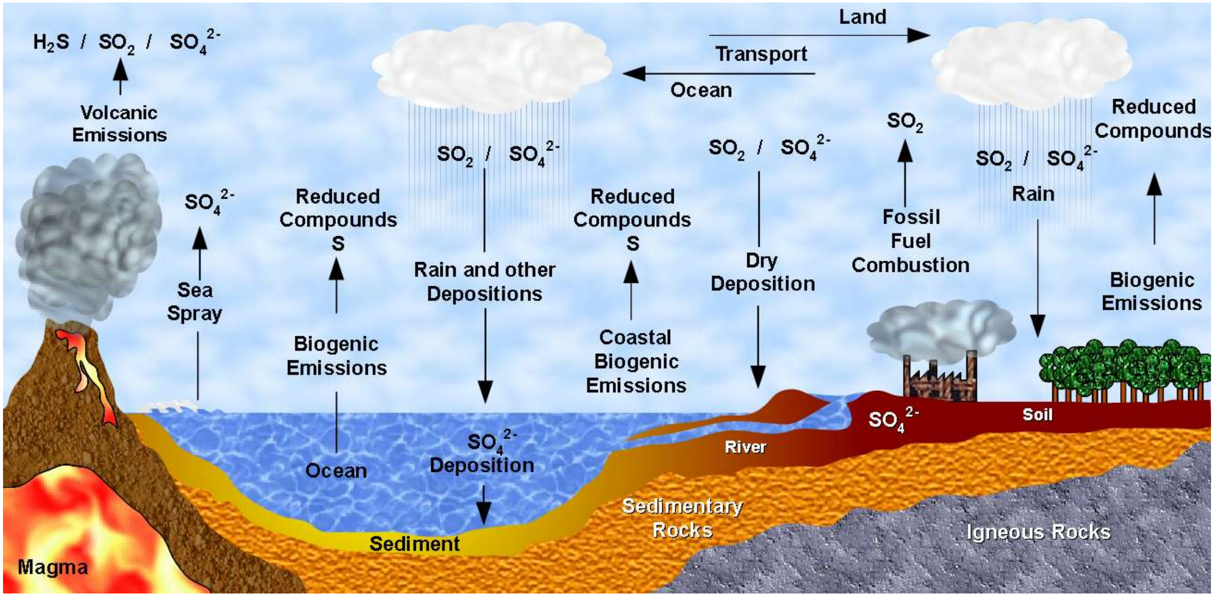


Fig. 22 The cycle of sulfur (S) [31]

3.3.7 The Cycle of Phosphorus (P)

In contrast to the nitrogen and sulfur atoms in the cycle is no phosphorus compound, which would be occurred as a gas in air in significant quantities. This significantly slows down and restricts the movement of this element in the cycle (Fig. 23). Phosphorus on Earth exists primarily in rocks and minerals (apatite and phosphorite) and in the form of phosphate is in freshwater and seawater and soil. Phosphorus is an important part of the bodies of plants and animals. Moreover, it is found in the bones of vertebrates plays an important role in the metabolism of any living organism. It is important during transmission and storage of energy in cells. [30]

On the cycle of phosphorus are also participating seabirds catching fish. Marine fish tissues contain a significant amount of phosphorus. In some areas of the country, it consists of droppings of these birds on the coast and islands so thick layers, **guano,** for which is undergoing active benefit as excellent **phosphorus fertilizer.** [30]

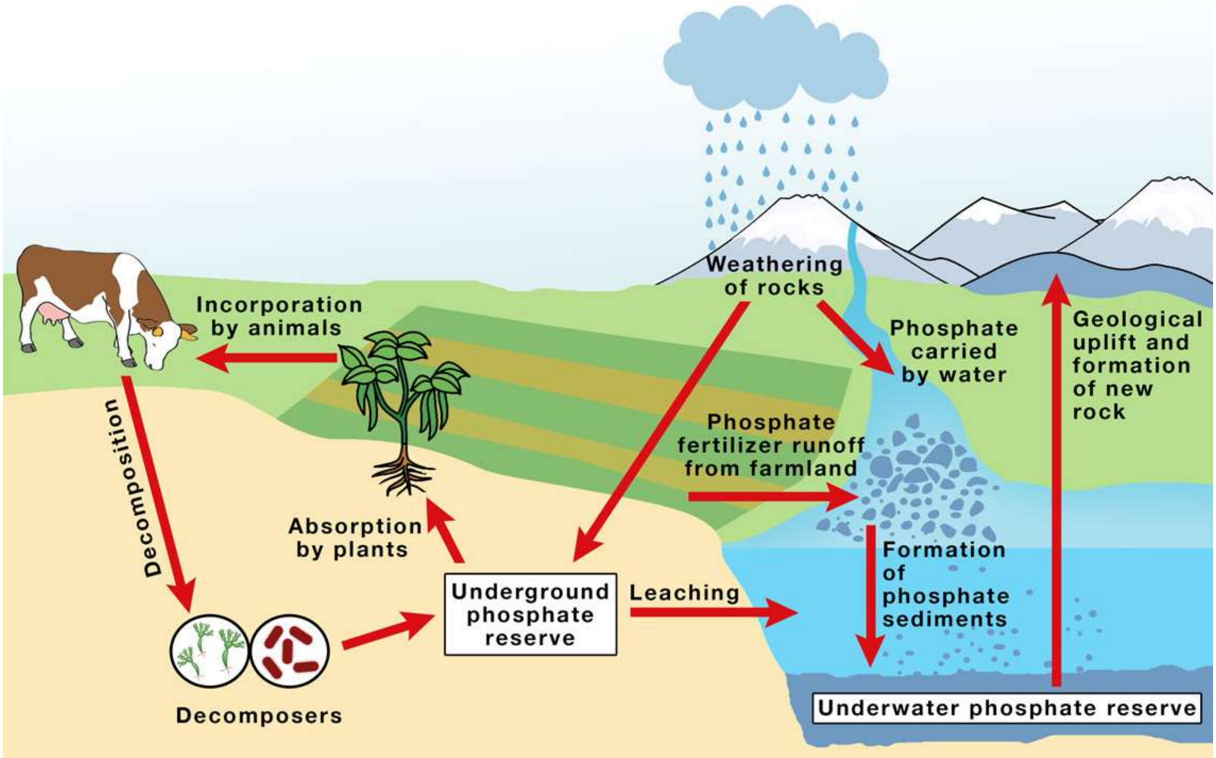


Fig. 23 The cycle of phosphorus (P) [32]

Thanks to human, there can be found in the generally, slow phosphor cycle some unnatural features. Man uses phosphates in the fertilizer as far as possible and as part of **detergents** - all sorts of detergents with degreasing effect. Both uses lead sooner or later to the deposition of phosphorus into waterways. And so the phosphorus gets into the seas or stored in sediments of natural lakes and artificial reservoirs. First, the phosphor in terms of re-use for a long time, lost in the sediment and the other is one of the causes of abnormal improving the nutrients of waters. [30]

The lack of air circulation severely limits the particular rate, at which the phosphorus may again come to the accessible forms of living organisms. If they are soluble and insoluble phosphates washed away into rivers and seas, there are stored in the sediments, their return to the cycle tied to a very long rock cycle. [30]

3.3.8 The Cycle of Other Elements

In addition to the above elements are circulating in the environment on the Earth, other elements and compounds. Roads that the planet passed in the environment are not as obvious or clear. [1]

The cycle of magnesium (Mg)

Naturally occurring as part of the magnesium dolomite. Magnesium is a necessary element involved in the transfer of phosphorus in the energy system of the cell ATP ↔ ADP. Adenosine triphosphate (ATP) to adenosine is split diphosphate (ADP) to release energy. [11]

The product is attached to **chlorophyll.** Due to the similarity of the structure of magnesium with sodium, magnesium is often the limiting factor due to the replacement of sodium.

The cycle of manganese (Mn)

Along with dissolved iron in the waters also it appears manganese. The bacteria responsible for the oxidation of iron also largely carried oxidation of manganese. Manganese is an element, which has similar characteristics and stratification times, such as iron. It occurs in nature most often in the divalent, trivalent and tetravalent form. Generally, the amount of soluble manganese by the solubility of the hydroxides, carbonates, carbonates and sulfides. Alkali-hydrolyzed and oxidized rapidly, already released as less soluble form in the oxidation state III, and IV. In nature, there is not only a chemical oxidation of manganese, but also biochemical oxidation of manganese bacteria (under neutral conditions occurs biochemical oxidation to produce bacterial biomass). In natural waters, manganese is present in very low concentrations that are not hygienically important. The problem arises in the case of sensor defects, once the concentration of 0,1 mg · l^{-1}, changes the taste of the water, quite apart from the problem of coloration of the material, in contact with water with a higher content of manganese. The development of manganese bacteria occurs at low concentrations. [11]

The cycle of calcium (Ca)

The calcium content in waters greatly affects buffering ability of calcium carbonate system. Calcium is an important component of the supporting structures of the bodies and skeletons of organisms. The waters were species indicating an increased calcium content or species-avoiding sites with a high concentration. [1]

The cycle of iron (Fe)

In aqueous media the iron ion present in divalent and trivalent form, which depends on the oxidation-reduction processes, the pH and the content of organic and inorganic complexing compound. In an environment without oxygen, i.e. and in ground water in the tank, the iron is present in divalent form, both Fe^{2+}, $[Fe\,(OH)_3]^-$. [11]

Iron cycle is closely linked to the cycles of phosphorus, trivalent iron phosphate is bound to an insoluble form. The complete precipitation of the iron in the form of iron phosphate occurs phosphorus limitation in organisms. Iron is found in waters at low concentrations, higher iron concentrations are characteristic of peat bog water. Regarding the significance of water supply and sanitary iron, this element is friendly, but very affecting sensory properties (in concentrations from 0,5 to 1,5 mg.l^{-1} is excreted in the form of iron oxide hydrate and causing turbidity. Overgrowth iron-causing bacteria technological problems, it is sufficient to very low concentrations of iron. In living systems is an important part of enzymatic transfer, by algae contributes to the functional structure of the molecule. [1]

4 GEOSYSTEMS OF EARTH

Systems of the environment that can be explored by geographical methods, can be designated as geosystems (from Latin. Geo = ground), because one of the characters is a bond to the Earth surface. They are complex systems, since their components are subject to various kinds of causality, with considerable differentiation in space and time. The system ideas about the structure and bonds geosystems are constantly evolving and are interpreted differently by different authors. In simple you can layout of geosystems to illustrate in Fig. 24. [33]

The geosystem of the Earth is the basis of life and consists of:

- Geosphere comprises:
  - lithosphere (earth crust): ► hydrosphere (lakes), ► pedosphere (land),
  - atmosphere (gaseous envelope of the Earth),
- Biosphere, consisting of:
  - phytosphere (vegetation),
  - zoosphere (animals),
  - mikroorganosphere (all organisms),
- Anthroposphere comprises:
  - human society,
  - human work (artifacts).

Each organism is find there a dwelling place that it can satisfy his living needs. The living space with its living requirements is referred to as the environment. [33]

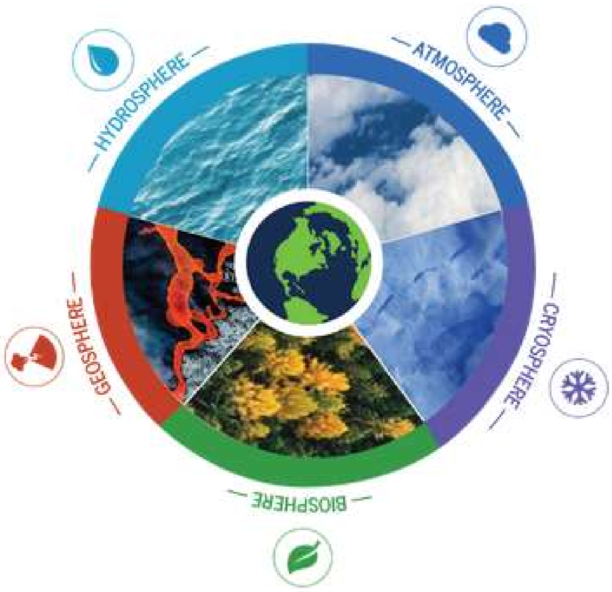


Fig. 24 The geosystem of the Earth [34]

4.1 Geosphere

The Earth is composed of concentric layers - geospheres (Fig. 25), arranged according to density. The solid Earth's body forms the Earth's core, mantle and the crust - these three layers are called internal geosphere. External geosphere consists hydrosphere, atmosphere and magnetosphere, which extends up to about 10 Earth radii. [1]

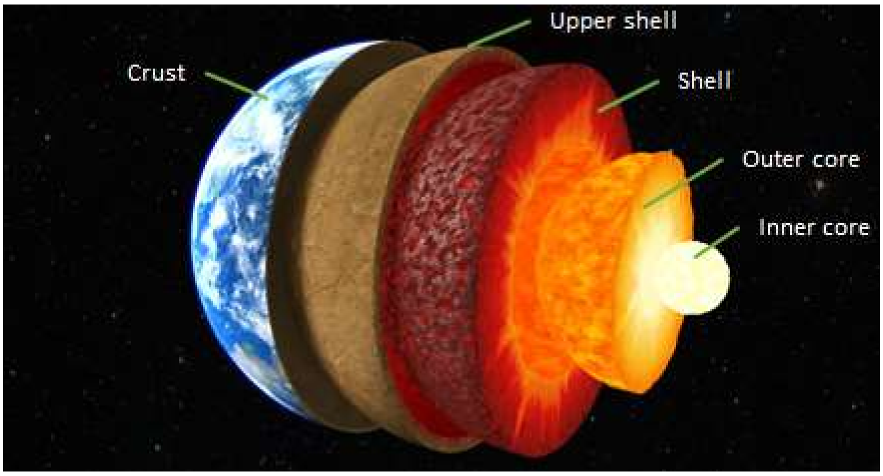


Fig. 25 Schematic representation of the individual layers of the globe [35]

Another meaning of the term geosphere indicates that part of the solid earth where people live and use it for their needs (Fig. 25). Geographical term "***geosphere***" (geographical or landscape sphere) indicates the countries or geographic sphere of packaging, including inorganic and organic substances. It includes **noosphere**, also containing substances that are the product of human activity. The term noosphere refers to the sphere of interaction of nature and human activity. Alternative designations for the noosphere are anthroposphere, technosphere respectively sociosphere. Geosphere has developed on surfaces in contact zone of the lithosphere, hydrosphere, atmosphere, pedosphere and biosphere. Geosphere includes all of the hydrosphere, the upper zone of the earth's crust and the lower part of the atmosphere - a total thickness not exceeding 40 km. Its basic ingredients are minerals that build Earth's crust, air and water masses including ice, soil cover and biomass. [11]

Fig. 26 High Tatras - Frog lakes [36]

Geographical sphere is a dynamic, evolving material system, receiving energy both from extra-terrestrial sources and also from the Earth's interior. Specific parts of the geosphere are called country. Between different parts of the geosphere, there is an uninterrupted exchange of matter and energy. Phenomenon in the geosphere has in most cases a cyclical repeatable character as a result of astronomical and geological phenomena (cyclic climate change, temperature, movement of glaciers, etc.). For the upper limit of the geosphere is considered the stratopause, since to this limit is expressed the thermal effects of the Earth's surface on the atmospheric process. [1]

4.1.1 Litosphere

Lithosphere (from lat. Lithos: stone) is uppermost, solid layer of rocky planets. On the Earth includes the Earth's crust and the uppermost part of the mantle. The lithosphere is sore for several plates that move relative to each other. This movement, its cause and consequences describes the theory of plate tectonics. Lithosphere - the Earth's surface is 150 million square kilometers, of which the seas and oceans 362 million km^2 (71 %) and the mainland 148 million km^2 (29 %). The thickness of the earth's crust is 35 km on land and at sea 5 - 7 km. The earth's crust is represented 102 elements. The decisive presence has 12 elements. Representation of more than 1 %, are: O, Si, Al, Fe, Ca, Na, K, Mg. [37]

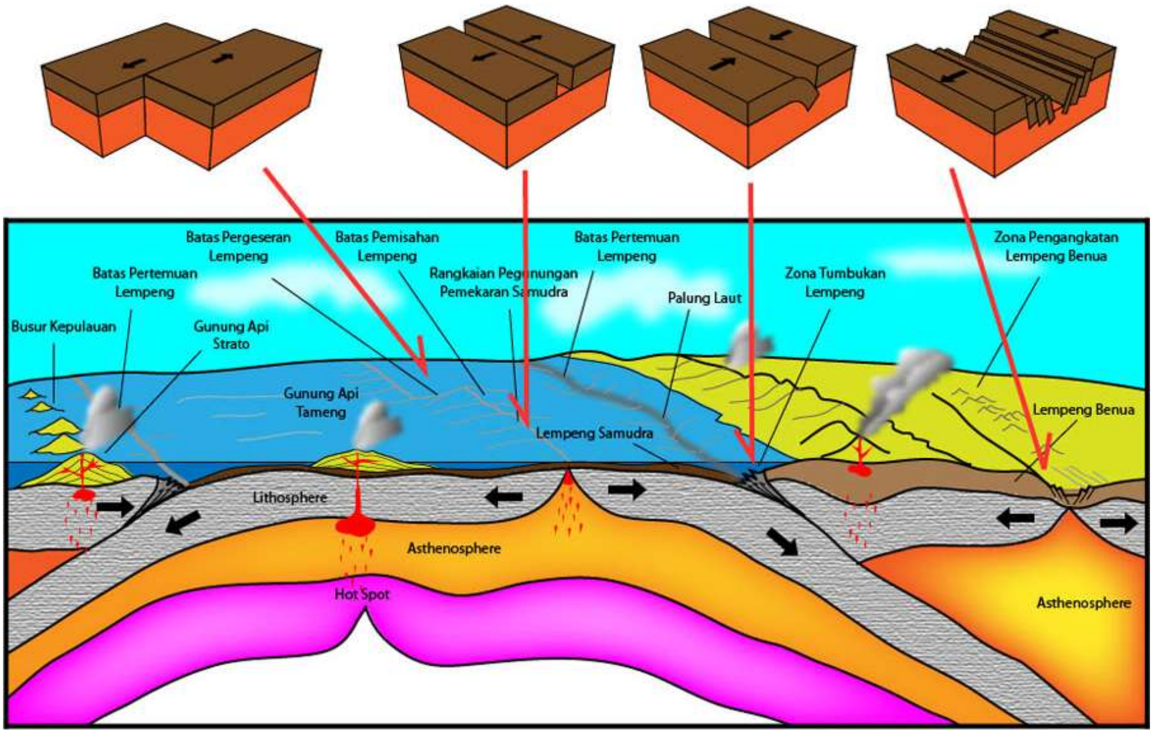


Fig. 27 The edges of tectonic plates [38]

The distinguishing feature of the lithosphere is not its composition, but its properties. Unlike the asthenosphere, which is plastic, the lithosphere seems brittle and has a lower density, making it "*floats*" on the asthenosphere. Lithosphere thickness is variable: from 1,6 kilometers beneath the ocean, to 150 km under the continents. Thanks, conventional convection and magmatic activity is its thickness increases with time. But this growth is not extremely fast, because it acts against weathering, calcareous, transport, store them in sedimentation ponds and subsequent absorption into subduction zones, oceanic trench. [37]

4.1.1.1. Pedosphere

Pedosphere is the soil cover of the Earth and is part of the geosphere. It consists of the uppermost part of the lithosphere and is localized at the interface of the lithosphere, atmosphere, hydrosphere and biosphere. [39]

Soil is considered a bridge between the living and the inanimate world. This view is related to the fact that most life forms extracted from the soil a large number of elements, either directly or indirectly, through the plant. [39]

Land accounts for only part of the dry ground. The residue forms the surface, covered with a layer of rock and mineral fragments resulting from the erosion of minerals. This part of the surface is called **mantlerock** or **regolith**. Regolith name is derived from the Greek words regos "*blanket*" and regret "*rock*". [39]

There are a large number of soil types. Their properties depend on the type of parent rock, the conditions of their origin and nature of the biosphere involved in their creation. Soils contain inorganic and organic substances and substances animate and inanimate. Although the relative proportion of the two components, organic and inorganic, may vary significantly, the typical soils contain about 95 wt. % Inorganic components. They represent minerals that are the product of weathering of different rocks. Typical inorganic constituents of soils are fine-grained form of quartz, limestone, dolomite, orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$), epidote ($4CaO._3(AlFe)_2O_3.6SiO_2.H_2O$), goethite (FeO (OH)), magnetite (Fe_3O_4), and manganese oxide, and titanium. The final product of weathering of rocks in the soil is inorganic colloids, which play an important role in the intake of nutrients in plant roots. Inorganic colloids often preferentially absorb toxic substances in the soil, therefore, play an important role in detoxification of various substances which would otherwise be passed into the bodies of plants. [11]

Soil organic matter represents plant and animal biomaterial situated in different stages of decomposition, bacteria, fungi and animals. Any land containing gaseous compound, in particular air, which, however, due to various degradation processes, has a different composition to that of air, situated in the low levels of the atmosphere. Water is a highly variable component representation. It will comprise from 25 volume percen of the soill and is in fact the right or colloidal solution of a number of inorganic compounds. The relative volume ratio of organic and inorganic components is different from the weight ratio. [1]

Branch of science dealing with pedosphere is **pedology**. Pedololy (of gr. **Pedon** - soil, **logos** - science, science) or soiree is a natural science dealing with the study of soil, its origin, classification, physical, chemical and biological properties. Scientists involved in the land called soil science. Practical use of the land is engaged in **agronomy**. [1]

Agronomists are generally land users, are mainly concerned about the physico-chemical and biological characteristics of the soil, while the Soil Science are primarily interested in the formation and relationship to their environment. This differentiation, however, in recent years, is losing (thanks Emerging green, view of land use). [39]

4.1.1.2. Hydrosphere

Water (Fig. 28) is the most widely used liquid substance on earth. It is mainly concentrated in the hydrosphere - water covers the Earth, which represents about 0,025 % of the total mass of the Earth. It comprises the waters of the oceans, which contain $1{,}4^{13}.10^{21}$ kg, representing a 98% share the rest falls on the continental ice ($2{,}3.10^{19}$ kg), water of rivers, lakes and groundwater (5.10^{17} kg) and biologically bound water. The water is concentrated in the solid state forms a layer, which is designated as the cryosphere. Into hydrosphere is not excluded the water in the atmosphere and the water chemically bound in minerals respectively, physically absorbed on the surface. [40]

According to the existence of phase transformations of water in the temperature conditions prevailing on Earth (these ratios are also retroactively affected by these changes), there is a significant interaction of the hydrosphere and lithosphere. This relationship can be illustrated by a local change in climatic conditions caused by vegetation removal, which significantly affects the extent of water transport in the atmosphere. This is caused by both the change in evaporation from the free surface of the Earth, as well as the surface of plant leaves (transpiration). Climate change can be observed even when changing the type of vegetation. Causal conditionality of changes in the atmosphere, with large interventions in surface layers of the Earth is not always clearly identifiable, since it is mostly a series of several parallel and subsequent partial storylines feedback. [40]

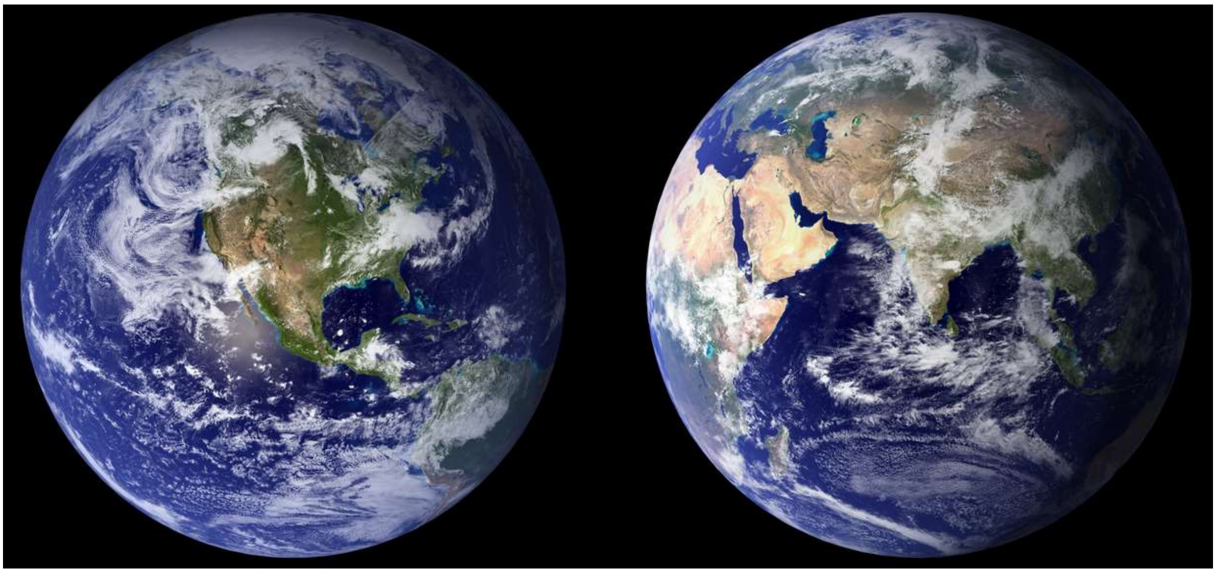


Fig. 28 Water covers about 2/3 of the Earth's surface [41]

Although the water in nature is in fact of multiple component system comprising inorganic and organic constituents, including a variety of live substances, naturally apply all special physical-chemical characteristics of the water which the substance as a pure chemical entity. From an environmental point of view are particularly important following characteristics [40]:

- **Very good ability to dissolve ionic compounds** - play an important role in transporting large range of substances, including fertilizers and waste products.

- **Transparency of water** - enables photosynthesis in living organisms and underwater.
- **Large evaporation heat and high heat capacity of water** - causes thermal stabilization in the bodies of plants and organisms and causes large thermal inertia in climate change.
- **Abnormal water density dependence on temperature (the highest density of water at 3,98 °C** - water layer, the temperature is cooled to this value is the most dense and sinks to the bottom) - it causes non-circulating waters in the thermal stratification (stratification) at which arise the results as independent and immiscible layers of different chemical, biological and physical properties. For example, the top layer has a higher content of O_2 as a result of photosynthesis and the lower one has the low content of dissolved oxygen as a result of biodegradation processes.
- **The lower density of ice as compared to water and thermo-insulating effect of ice on the water** - enables the survival of aquatic flora and fauna, when the outdoor temperature is below freezing. The density of liquid water at 0 ^oC = 1,00 $g.cm^{-3}$, but at this temperature, the ice has a density of 0,94 $g.cm^{-3}$. Water is one of the few materials (e.g. Si, Bi, Sb, and some alloys), where the solidification increases in volume. If it were otherwise and the water should be at she shrunk freezing, the ice would not float on the water, but sink to the bottom of lakes and oceans. The ice on the bottom of the ocean, by the sun's rays, do es not penetrate, so the oceans, except for a thin layer of liquid on the surface in warm weather, would be eternally frozen solid material.

The term "*water*", unlike the clearly defined chemical substances in the broad sense is understood as the liquid, which forming a main weight proportion of streams, rivers, lakes, seas and oceans, alternatively groundwater accumulation. From chemical view, this is in fact mostly dilute solutions of various salts, with the dissolved gaseous components, and in most cases comprising a suspended solid with a very variable chemical composition and distribution of particle size. The main components of water include inorganic cations Ca^{2+}, Mg^{2+}, Na^+ a K^+, and anions Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}, OH^-, $HSiO_4^-$. Other components are aluminum, silicon dioxide, carbon dioxide, hydrogen sulfide and oxygen. The total concentration of these components is changed to a large extent of about five orders (1 mg to 10 $g.l^{-1}$ of water). [40]

Sea water, which represents the largest share of the hydrosphere, contains in one liter about 35 g of dissolved inorganic salts. [1]

Fresh water only represents a fraction of a percent of water on Earth's surface. But wherever fresh water accumulates, it becomes a rich habitat of living organisms. Freshwater habitats are found almost everywhere in the world, from the equator to the poles. Only in deserts, where the water is scarce, and in the polar regions, where water freezes into ice, freshwater life is totally absent. [1]

Water has in a broader meaning environmentally significant role. Water quality, its quantity and availability are among the most important parameters that throughout human history would significantly affect and are still affecting the settlement of the country as well as quality of life. Although the deployment of human habitation in the country is parallel affected by a number of parameters, by the availability of water resources, and it is one of the defining. Except to basic physical and chemical properties of water, which include temperature, density, dissolved and dispersed components or content and species composition of micro-organisms, it is also important information about the transport of water and changing its properties. The above topics dealing with hydrology, which is within limnology dedicated group of flowing waters and under water ocean oceanography.

The water cycle (or **water** or **hydrologic cycle**) is the term, which mark the permanent circulation of water on the Earth, driven by solar radiation and gravitational forces of the Earth. The cycle involves the water in the atmosphere to vapour, and can be in the surface as the form of the river, lake and sea water as well as below the surface in the form of ground water. As the water passes through the phases of the cycle, it changes its state from gaseous, liquid to solid phase. Water cycle is the main subject of investigation **hydrology**. [11]

The water cycle has not clearly defined start and end. Water molecules are moving continuously across the hydrosphere by various physical processes and do not necessarily completes all stages of the cycle. From the evaporation from the oceans and seas, through the formation of clouds, condensation of water in them to form rain drops or snow flakes and a subsequent fall to the surface in the form of precipitation. The whole cycle is concluded transport of water in river flows back into the sea. The total amount of water in the cycle is constant, therefore the amount of water leaving from a source (reservoir) to the quantity of water that enters into it. [11]

Remaining water in the reservoir

Each of natural water reservoirs stores water for various times. E.g. water in the form of soil moisture is retained for about two months, while deep stored reservoirs of underground water can have 10 000 years old. The residence time of water, in a given reservoir, is estimated on the basis of conservation of mass, so that a certain amount of water in the reservoir is constant and based on measured or calculated losses / habitations down the hold time. The second method (rather focused on groundwater) is based on isotopic techniques. [40]

Impact the water cycle on climate

Evaporation of water from the oceans has serious consequences on the overall climate of the Earth. On the passage of water from the liquid to the gaseous state, it is necessary to supply a large amount of heat. If this were not absorbing the heat, the average temperature of the surface of the Earth would be about 67 °C. [40]

Changes in the water cycle

Human activity significantly affects the water cycle, whether it changes the level of groundwater by agriculture, or the absorption capacity of the soil deforestation (or afforestation), or the construction of hydropower plants (dams) and the subsequent effect on the amount of water in rivers and urbanization. From the natural phenomena, the water cycle is most affected by the temperature of the surface (in the last ice times were the amount of evaporated water less than today). [40]

4.1.2 Atmosphere

Atmosphere or the Earth's atmosphere is a gas cover, which is surrounding of the Earth. It has no significant upper limit (coincident with the space) and rotates together with the Earth. It protects us from harmful cosmic rays, harmful solar radiation and the solar wind. It takes place in the formation of weather. It contains the air we breathe. Without it there could not be a life. The gases that form the atmosphere keep the gravitational force around the Earth. The atmosphere is most often divided into parts: the **troposphere, stratosphere, mesosphere, thermosphere and exoatmosphere**. Each of them contains a mixture of gases, which density with distance from Earth is decreasing. Already at a height of 100 km above sea level (i.e. in the lower thermosphere) is laying so called. Sphere Kármán line, it means the boarder, which by the IAF (International Astronautical Federation) is considered as the beginning of space (outer space). [42]

The electromagnetic waves of different wavelengths enter into the atmosphere from the surrounding space, but atmosphere on long distances absorbs most of them. It passes only radiation having a wavelength between 1 cm to 11 m (radio windows), with a wavelength between 300 - 1100 nm. This area is called the optical window despite the fact that it comprises a portion of the infrared and ultraviolet radiation. The optical window is particularly important for life on the Earth. [42]

In terms of changes in temperature (Fig. 29) with height in the atmosphere of the Earth atmosphere subdivided into multiple layers from bottom to top [11]:

- **troposphere** (the biosphere), it is bordered by thin tropopause,
- **stratosphere** (s ozonosphere), it is bordered by a thin stratopause,
- **mesosphere** (the lower ionosphere), it is bordered by a thin mesopause,
- **thermosphere** (the upper ionosphere, and northern lights), it limits the term pause,
- **exosphere** (the magnetosphere), crossing interplanetary space (often considered part of the thermosphere).

The **troposphere** (from gr. **Tropé** - turnover, **sphera** - sphere) is the innermost layer of the atmosphere. With a height, here the temperature drops an average of 0,65 °C at 100 m (definition according to ISA - International Standard Atmosphere). Its temperature, which is generally in the range of approximately 17 °C to - 52 °C. [1]

The **troposphere** is the densest part of the atmosphere and forms 80 % of its weight. It reaches a height of 8 -10 km over the poles, 11 km in the temperate zone and 16 - 18 km above the equator. Its composition is relatively constant. It contains about 78 % nitrogen, 20,9 % oxygen and small amounts of other gases. Although the content of certain components of the atmosphere is very low, change their concentration may have on the environment very significant impact. A typical example is the presence of ozone, which is present in the atmosphere at very low concentration (a maximum of about 20 - 30 kilometers, reaching 3.10^{-8} vol. %. Ozone absorbs ultraviolet portion of sunlight, and the reduction of the content of the very negative implications, first, in extra damage to living organisms by UV radiation, and cause long term changes in the temperature of the atmosphere and the earth surface with a series of other effects affecting the downstream environment. There is a life in the troposphere, clouds are formed, and it takes place in most weather-related phenomena. The troposphere also contains all the water vapor. The mean pressure in the lower part of the atmosphere is about 100 kPa (the so-called sea level, standard pressure of 103,3 kPa) at the top has only 20 kPa. Troposphere especially is heated by the Earth's surface and little sun. Another layer is the **tropopause,** where the temperature does not decrease with height, and after the **stratosphere**. [42]

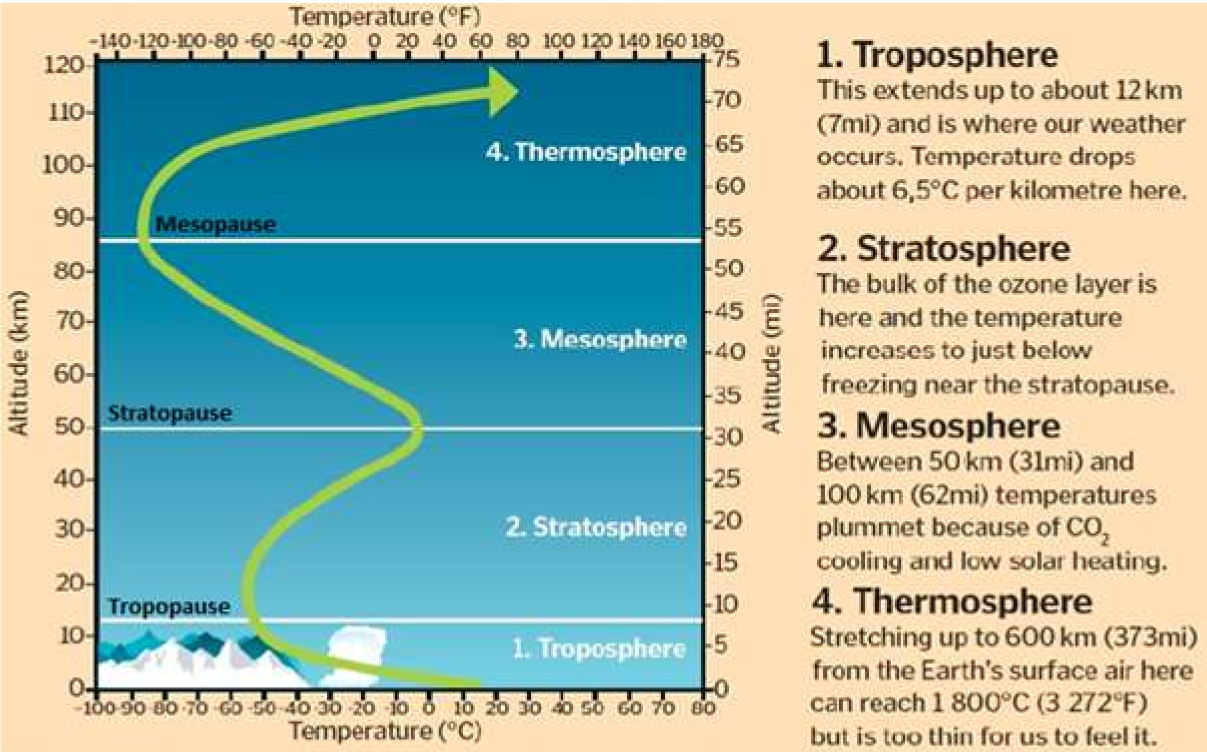


Fig. 29 The dependence of the temperature of air on the distance from the ground [43]

The troposphere is also referred to as "*lower atmosphere*", mesosphere and stratosphere as "*middle atmosphere*" and thermosphere and exosphere as "*upper atmosphere*". At a height of 500 - 600 km, the thermosphere (ionosphere) gradually passes into the exosphere, which extends towards the space up to several thousand kilometers. All gas molecules to be found here are on their way into space. [42]

The overall composition of the atmosphere is shown in Tab. 2.

Tab. 2
The overall composition of the atmosphere in numbers [1]

Gas	Share, according to NASA
Nitrogen (N_2)	78,084 %
Oxygen (O_2)	20,946 %
Argon (Ar)	0,9340 %
Carbon dioxide (CO_2)	365 ppmv
Neon (Ne)	18,18 ppmv
Helium (He)	5,24 ppmv
Methane (CH_4)	1,745 ppmv
Krypton (Kr)	1,14 ppmv
Hydrogen (H_2)	0,55 ppmv
The above composition does not include a dry atmosphere:	
Water vapor	highly variable proportion; generally above 1 %

The atmosphere is essentially a mixture of [11]**:**

- 99 %: 10 gases, in particular nitrogen and oxygen,
- 1 %: argon, and a very small amount of carbon dioxide, helium, neon, carbon dioxide, ammonia, carbon monoxide, ozone, and water,
- contaminants such as fumes, smoke particles, salt, volcanic ash.

Atmospheric composition also depends on the height. In the homosphere (i.e. to a depth of 95 km, which is usually called the "*air*") it is still the same - with the exception of CO_2 (the proportion varies with time and altitude), ozone (the proportion varies with altitude) and water in all state (mainly water vapours, the water is present in the amount of about 10 km of the atmosphere 4 %). [42]

4.2 Biosphere

Biosphere or living layer of the earth, precisely geo-biosphere, is an area of the Earth, inhabited by living organisms. It consists of top of the **solid earth's crust (the lithosphere), the casing soil (pedosphere),** water container (hydrosphere) and lower layers of the atmosphere (the atmosphere). In the older sense, the biosphere and simply mark the sum of all organisms on earth. It can therefore be said that the biosphere consists of all the Earth's ecosystems**.**

The biosphere is characterized by self-regulation, self-renewal, circulation of matter and energy flow. [11]

Biosphere as part of landscape sphere examines **Biogeography**. It focuses on two distinct landscape elements: **flora and fauna**. [3]

The biosphere consists of a large number of different biomes and ecosystems. Earth's atmosphere contains the elements necessary for life organisms and protects them from the harmful effects of the sun and the impact of small bodies in the universe. The individual components of the landscape in various ways affect on living organisms as environmental factors (water, light, heat, soil, relief).

Plants and animals join together and form a community of plants, called **zoocoenosis.** Legitimate set of plants and animals, which apply their own rules of coexistence is called **biocenosis.** [10]

Fig. 30 Spring flooding on the Danube [45]

4.2.1 Phytosphere

Plant communities (Fig. 31) – part of biota, the concrete form of the cohabitation of populations of several species of plants in the same environment, which is characterized by the comparatively stable species composition, layout and physiognomy as a reflection of ecological conditions, inside social relations and historical development. [3]

Fig. 31 Badínsky primeval forest – Kremnica Mountains [46]

The main task phytocoenoses causal analysis is to examine the relationships between plants and the relationships between plants and the environment. These direct links are divided into parasitic, symbiotic, epiphytic, mechanical, biochemical, physiological. Indirect relationships usually have a universal character, acting through the environment. [1]

When studying plant landscape sphere distinguishes between the following terms [13]:

- **flora** - we mean as an inventory of plant species, which are one part of the landscape sphere of the Earth,

- **vegetation** - a set of plant communities (plant communities) in a particular territory landscape sphere of the Earth,
- **vegetation cover** - a set of premises vegetation types that are found in the interaction and form the vegetation mosaic landscape sphere of the Earth,
- **vegetation type** - any set of products defined in the country of physiognomic, or physiognomic-ecological features, or based on species composition,
- **formation** - vegetation types defined on the basis of physiognomic characters of plants. They may form themselves into groups and classes in the formations.

In addition to general morphological characters and physiognomic plant communities it needs to be analyzed more closely and notice signs that are typical of every community.

Among the various features of plant community members and track community that we should pay attention we include [10]:

- **habitus** - appearance (plant height, thickness, size of leaves, branching in trees, crown shape and the like),
- **age** - especially for trees. (Striking are the differences in the plants in the first year, they created ground floor rosette and bloom the following year or years later),
- **phenological phase** - recorded certain life stages of plant species distinguishes several periods: Early Spring, Spring (early and full), summer (early and full), fall (early and full) and winter,
- **vitality** - life (individuals can survive in a particular environment their entire life cycle or only part of this cycle, individual species in different environments have different life),
- **Life Form** - we distinguish 5 types of life forms according to the environmental impact of the environment (fanerophytes, chamaephytes, hemicryptophytes, cryptophytes, therophytes),
- **Dominance** - The coverage - to reflect all of the individuals of a species on an area basis, then finds the percentage of species,
- **abundance** - abundance - pinpointing frequent or estimate the relative abundance of each species,
- **combined estimate** - at lower levels reflects the abundance, at higher levels increase dominance,
- **density** - density - the number of individuals of a species on the unit area of a community,
- **homogeneity** - uniformity - is a regular occurrence of individual species in plant communities and individuals the same distance apart,
- **frequency** - specifies (in %) of individual species regularly or randomly placed lands in plant communities.

You may notice more features and many other characters, such as [11]:

- **stand characteristics** (topoclimatic, moisture conditions, soil reaction, etc.),
- **production characteristics** (fodder, melliferous potential healing effects, etc.),
- **ecozoological characteristics** (scarcity, vulnerability, etc.).

4.2.2 Zoosphere

Set of animals called zoocoenosis. Along with the plant communities are developed together at the location and form a biocoenosis. Plant and animal species (Fig. 32) with the other components of the landscape of the site consists biogeocenosis (ecosystem). In the healthy nature of the representation of species are balanced. Large human intervention, this balance is disrupted and often causes calamities such. creeping calamity on forest and agricultural cultures. [1]

Fig. 32 Roháč is dependent on oaks throughout its development cycle [47]

Most animals are existentially dependent on vegetation, providing them with their food. Our fauna is divided into animals steppe, forest and mountain. A special group consists aquatic animals. In the steppe fauna adapted to prevailing warm environment. The mammals are represented here the most rodents such as rabbit, ground squirrel, vole to eat plants and carnivores that feed on them, such as a fox or weasel. Bird species are represented especially by gallinaceous birds that fly sick, but fairly well run. These include, for example, partridges and pheasants. There is also a strong presence of insects. The forest fauna is divided by the type of forest. Most animals are concentrated on the edges of forests at low altitudes. He lives here especially many species of songbirds as well as insects and carnivorous animals. [10]

The animal kingdom adjusts to the trees, others live in deciduous and coniferous forests in the other. For deciduous forests are characterized, for example, woodpecker, titmouse, the nightingale, forest cat, wild boar, etc. For coniferous forests are characterized, for example, Carpathian newt, brown bear, marten owl, lynx and others. Aquatic fauna is not divided only by climate change, but also by water purity, oxygen content, and aquatic vegetation. Other aquatic animals are found in mountain rivers and other again in lowland streams. Specific fauna is encountered at high altitudes above the tree. From the mammals is a typical alpine chamois and marmot second. From birds is reddish mountain bird. From the class of insects live here butterflies. [11]

4.2.3 Micro-organ sphere

In the nature are occurring microorganisms in pure culture exceptionally, they produce microbial communities. Interrelationships between organisms and their environment deals with ecology [48]. Space inhabited by microbial communities is called **biotype**. Habitats and community create the **ecosystem** [48]**:**

- biotic component (microbial community),
- abiotic components (the physical and chemical conditions).

Microorganisms can modify their activities outdoors.

Effects of the environment on microorganisms - The life and activity of micro-organisms depends on the development of the external environment and at the same time by [48]:

- sources of nutrients and metabolic energy,
- physical, chemical and biological conditions.

Characterized by the ability to quickly adapt to current conditions; This ability is called **adaptation**. This is manifested [48]:

- by the enzymes,
- changes in the morphology of the cell.

The size of microbial systems are varies (river, lake, root system of plants, surface plants and animal species, oral cavity, etc.).

Ecological niche - defined quantity of resources (nutrients) and physico-chemical conditions of the location.

Autochthonous species - bacteria species colonized the defined site from the beginning. Typical of habitat, natural.

Allochtonne species - their presence depends on the currently elevated concentrations of nutrients or delivery of specific substances.

Under normal conditions (neutral pH, nutrient excess, sufficient water) are obtained a significant number of species in the environment.

In extreme conditions are present fewer species, but more one of individuals of the species.

Monospecific community - is made up of only one type.

Dominant species - populations occurring in greater density than others.

Community of microorganisms is an open, dynamic system.

Dissemination of microorganisms [48]***:***

- **Air:**
  - the largest number of above the soil surface,
  - above the sea more microorganisms at a greater distance from the surface level, continental origin.
- **Water**:
  - significant importance in the ecosystem has at least 106 organisms / ml.,
  - main soil microorganisms.
- **With animals:**
  - microorganisms present on the skin and the intestinal tract,
  - rapid spread of the disease.
- **Inanimate objects:**
  - consequence of direct contact with these objects and the subsequent transfer,
  - clothes, books, toys, handles, floors, pools, food.

The share of microorganisms to geochemical transformations of the biosphere [48]**:**

- **mineralization** - conversion of organically bound elements into inorganic,
- **immobilization** - conversion of inorganic elements in organic complexes,
- **oxidation**,
- **reduction**,
- **fixation** or **volatization**,
- **conversion of the gaseous form on non-gaseous ones, and vice versa,**
- **biogenic elements subject to cyclical transformation**.

Microorganisms as symbiotic partner [48]**:**

- **symbiosis** - close interaction between two different organisms,
- **mutualism** - coexistence beneficial for both partners,
- **parasytizmus** - one partner lives at the expense of another,
- **neutralism** - none of the partners has no influence on the other,
- **ectosymbisis** - one of the partners located outside the cell of the second,
- **endosymbiosis** - one of the partners is located inside the second cell.

4.3 Anthroposphere

Anthroposphere is the area of land and the nearby cosmos, where it lives permanently or temporarily and which penetrates humanity / e.g. sonda Pioneer Probe /. It does not image any separate sphere, but extends to any part of the biosphere, which is affected by anthropogenic activities of human civilization. [49]

4.3.1 Human Society

Man as a part of human society, his technical work and at the same time use of land, form the anthroposphere, which is part of noosphere. The **noosphere** is a sphere, which is subject to human society. It is a space, which consists of information and human knowledge that are collectively available to man. [49]

4.3.2 Human Work (artifacts)

Human work (artifacts) is all that has created and creates man (Fig. 33). Human intervention in nature can be accidental, but as a rule they are aware and controlled. The influence of artificial human intervention in the biosphere occurs disruption of the natural cycle of substances and elements, creates an artificial scattering elements and their concentration. For example, in agriculture, in the application of fertilizers at liming and chemical treatment of cultivated crops they disperse many biogenic elements, as well as heavy metals. Conversely, mining, and processing the materials extracted artificially concentrated many elements, which are then used in many industries. [49]

By human activity arises in the biosphere new areas, whose chemical composition is different from the original composition of the biosphere, occurs in these new substances and new forms of occurrence of elements that disturbes the natural metabolic cycle in the biosphere. These are the industrial and urban centers of the country affected by mining and processing of ores, cutting of forests and forested landscapes, roads, highways and even. [3]

Environmental pollution with chemical compounds is one of the most effective destruction of the biosphere and is the result of anthropogenic activities of man. [10]

Fig. 33 Nuclear power plant Mochovce [51]

5 NATURAL RESOURCES AND THEIR ACQUISITION

Man is directly dependent on the material component of the environment by his biological need, i.e. by receiving air, water and food. As a result of its reasoning, humanity also uses other components, including the so-called meeting of living needs. The development of human society is heavily dependent on natural resources. It can be determined by their lack or potential exhaustion. Since it is necessary to approach the use of natural resources very responsibly. [10]

5.1 Classification of Natural Resources

The criteria for dividing natural resources are based on their characteristics, nature and use. The most common is the division of natural resources into resources [11]:

- circulating and non-circulating,
- reproducible and non-reproducible,
- exhaustible and inexhaustible.

According to characteristics, nature and use, biosphere resources are divided into those referred to in Fig. 34. [3]

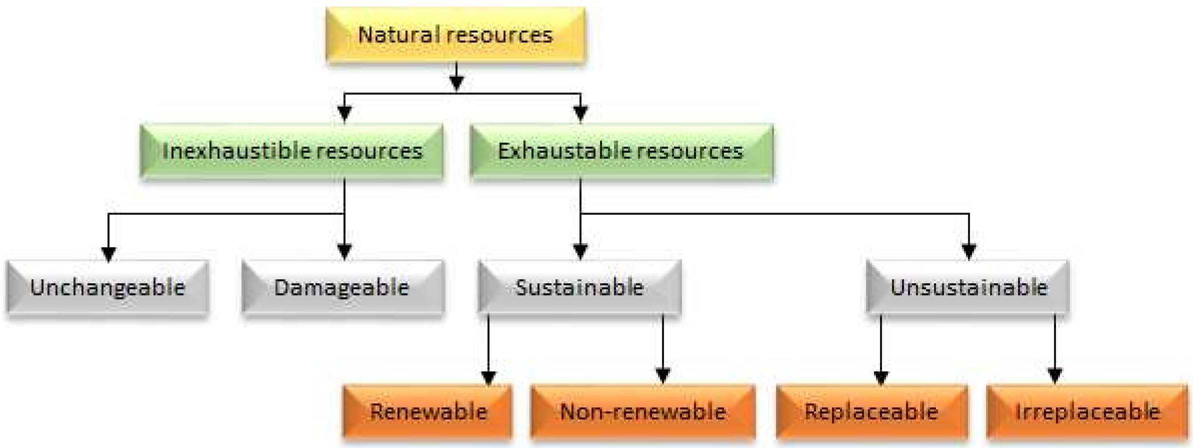


Fig. 34 Classification of natural resources [1]

Inexhaustible resources are unlimited biosphere resources, the use of which is minimal in terms of the duration of human society. These sources belong to the basic characteristics of the Earth (gravity, energy content of the nucleus, sunlight, water, wind). We can't use up resources. [11]

Unchangeable resources are those that the company cannot qualitatively change by its activities. These are, for example, sunlight, wind, etc. [52]

Damageable sources are those where use may be reduced due to negative effects, e.g. on water, air due to pollution. This resource must be given close attention from the point of view of environmental protection. [53]

In the **group of exhaustible** resources, we include mineral resources, which are of key importance for economic activity. Their stocks are basically limited. They must therefore be used economically.

Line: Exhaustible, sustainable, renewable resources are those that can be sustained and renewed at a cost of significant costs and work (e.g. soil fertility, agricultural crops and animals).

Line: Exhaustible, sustainable, non-renewable are those resources where, after exhaustion, recovery is not possible in a relatively short time compared to the time of human existence (e.g. landscape, devastated soil, some animal and plant species).

Line: Exhaustible, unsustainable, substitutable are resources whose use can be extended by maximum economy or replaced by other resources. This is the use of mineral wealth resources that can be replaced by synthetically and man-made materials (e.g. diamond).

Line: Exhaustible, unsustainable, irreplaceable resources that can only be used once, their stocks are limited (e.g. fossil fuels).

By nature, they are divided into resources [52]:

- abiotic,
- biotic.

Abiotic sources include [53]:

- mineral wealth,
- water, air.

Biotic sources include [54]:

- flora
- Fauna.

All types of natural resources exist side by side, intertwine, interact and interact with each other. Therefore, when using them, it is necessary to apply a systemic approach and to choose the options that are most appropriate in terms of exhaustability or harmfulness. One way is to use the possibility of recirculating natural resources (Fig. 35). [52]

Changes between natural resources are qualitative or quantitative in nature, with each induced change in a particular natural environment triggering a change in other natural resources of the biosphere. [52]

The main types of natural resources are [53]:

- solar radiation,
- soil,
- water (surface, underground, soil),
- air,
- mineral wealth,

- flora,
- fauna,
- specially protected parts of nature (rare natural objects, landscapes).

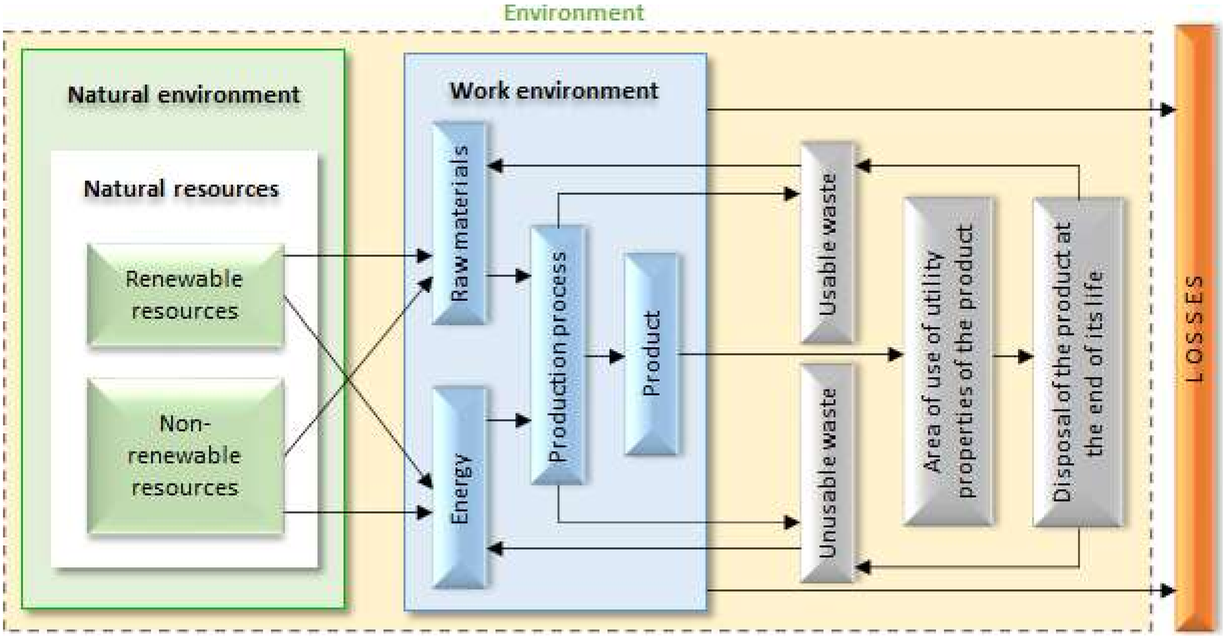


Fig. 35 Recirculation of natural resources

Primary energy sources

Some of the natural resources are characterized by energy potential, which is referred to as the primary source of energy. The designation is based on the requirement of the possibility of producing secondary energy, in particular electricity from the primary source.

The prerequisite for the viability of the whole company is sufficient energy, which is able to set in motion, maintain and develop the activity of the entire production and technical base of the company. [52]

Primary energy sources shall be the following natural resources [53]:

- solar radiation,
- earth heat,
- nuclear energy,
- water,
- wind,
- fuels,
- other unconventional sources.

Renewable, i.e. virtually inexhaustible, natural energy sources originate mainly from solar energy that falls on Earth and to a small extent (estimated around 3 %) in the radioactive decay of earth's core isotopes, in the movement of planets and in radiation coming from space (Tab. 3) [53].

Tab. 3
Basic breakdown of renewable energy sources

Source	Usable form of energy
Radioactive decay inside the Earth	Geothermal energy
Movement of cosmic bodies of the Sun, Mescaca and planets	Flap energy (tidal energy)
Space radiation	Solar radiation Sunlight (Atmosphere, Hydrosphere, Lithosphere) Watercourse energy Wind power Sea wave energy Live matter energy (biochemical energy)

Geothermal energy (electricity, **heating), tidal** energy (electricity), nuclear **energy** and partly watercourse energy are industrially **used from these sources.** The industrial use of these resources shall be preceded by detailed studies, the results of which shall be verified on pilot plant locations. It is mainly about **the use of sunlight and heat, wind and biochemical energy.** Meanwhile, the use of additional primary energy sources encounters technical problems related to low equipment efficiency and high investment costs. [54]

The share of primary energy sources used to generate electricity is constantly growing and is a picture of industrial maturity and standard of living. [53]

5.2 Food and Agriculture

Food is an essential natural resources essential for the nutrition of all people. These are renewable resources, which are mainly provided by agriculture, in some countries also significantly by **fishing and fishing** and, to a lesser **extent, by pastoralism** and **hunting.** [55]

Nutrition problems occur in both developing and some developed countries. While poor countries suffer from food shortages (especially proteins) and many people are malnourished in them, in rich countries, excessive consumption, inappropriate composition and the resulting obesity occur in rich countries due to food surpluses. [55]

A very important objective is the production of valuable and harmless food. Given the current technical and technological equipment, as well as the contamination of basic agricultural products (raw materials) with certain pollutants, this is also a difficult task for us. Today, thousands of ingredients are being used in food as food production and treatment techniques progress. These include nutrients, artificial flavours and fragrances, protective agents, anti-oxidation agents, emulsifiers, stabilisers, etc. Although great efforts have been made to introduce standards regulating their use, knowledge of the consequences of their long-term use is insufficient. Some ingredients are suspected of carcinogenicity, others may be changed to carcinogens

The **so-called Green Revolution** [55] was linked to the use of newly bred varieties and to the overall intensification of agriculture. The level of nutrition in developing countries has temporarily improved and led to a substantial increase in meat consumption in these countries. However, it has also affected population growth. However, some negative consequences of the Green Revolution, which concealed several dangers for further development from the outset, have also begun to show [55]:

- the **high yield varieties used** were very demanding for balanced conditions and hated drought, for example,
- the use of **large quantities** of pesticides has led to mutations and the development of resistant forms of insects, which consume a significant part of the harvest,
- the use **of large quantities of manure** has often led to the degradation of groundwater into which part of the chemicals have been washed,
- **the culling of local varieties which, although not of high yields but were adapted to local** conditions and were resistant to climatic fluctuations, led to the impoverishment of the genetic basis of cereals,
- the **non-semage** of storage facilities and **distribution** led to large production losses; it is reported that losses accounted for a quarter to half of the harvest,
- the need for and higher inputs into agricultural production (costs of seed, fertilisers, pesticides, etc.) has led to a further wide increase in the gap **between rich and** poor in the various areas of developing countries,
- the **rapid population growth** has created a number of other problems very serious for the future development of human society.

Consequently, changes in farming methods have also led to agriculture going from self-consumption to export production in **many developing countries.** Basic foodstuffs then had to be imported here, which resulted in large losses and rising food costs.

A clear analysis of the problems associated with agriculture's relationship with environmental, ecological, economic and social phenomena shows how complex the current situation is: the initially extraordinary success of science, which was linked to the hopes of nutrition of millions, ultimately **provoked and deepened serious global divisions in a system of complex contexts.**

The **increase in** meat consumption leads to large areas of land being used for the cultivation of fodvers - approximately 38 % of cereals in the world are used for feeding cattle. However, there are again huge differences: while in industrialised countries the intake of animal protein is around 60 g per person per day, in developing countries it is on average only about 13 g.

Part of the animal protein for human consumption is obtained from fish (about 16 %) [57], **mainly by sea fishing** in coastal waters. However, it has already reached such a high level that it cannot be further expanded, since it would make it impossible to reproduce fish sufficiently. Until now, total food production has grown a little faster than the population. There would therefore still be enough food for the current population of people in the world if they were evenly distributed. This is not the case and an estimated **13 million people die every year as** a result of hunger [55].

Humanity has **other possibilities to** increase agricultural production both by expanding managed land and by intensifying agricultural farming.

The increase in agricultural crop yields (agricultural intensification) is linked to higher energy consumption in cultivation, an increase in the proportion of irrigated areas and the consumption of chemicals - fertilisers and biocides.

Total fertiliser consumption is increasing - it is currently higher than 140 kg per hectare in industrialised countries (about 80 kg/ha in 1970), in developing countries it is already less than 80 kg per hectare (in 1970 only less than 20 kg/ha) [55]. Similarly, the use of pesticides is also increasing as a result of the pollution of groundwater and surface water into which these substances are washed away.

The consequence **of nitrogen overeating is known.** In plants, nitrate reduction produces toxic nitride (they affect mainly red blood cells) and nitrozoamine (apparently carcinogenic substances). At the same time, the intake of nitrogenous substances into and from water usually increases. In most surface waters, nitrate levels (mainly by flushing out of the soil and acid rains) have risen so that their concentration varies from 3 to 30 mg per liter. High nitrate intake can lead to the breakdown of red blood cells (methaemoglobinemia) in infants. It is also high **in phosphorus**, reaching several tenths in places and exceptionally even up to 1 mg per 1 liter of water 0,2 mg of nitrogen and 0,02 phosphorus per liter of water are sufficient conditions for the formation of water bloom (eutrophication).

The main **problem with the use of biocides** is usually insufficient selectivity (this means that they do not only act on the type of organism against which they are intended), and often a long period of inactivation (the substance stays in the environment for too long, only slowly degrades, often also due to the emergence of other toxic intermediates). Contact insecticides, for example, usually destroy not only the pest, but also its predators and parasites, so they completely disrupt regulatory relations in the ecosystem. [55]

Even if biocides sometimes manage to eliminate an unwanted population, it may not be a win. This can free up space for another species, which unexpectedly overgrows and manifests itself as a pest. If the biocide is used again, its concentration in the environment begins to increase to the extent that it accumulates dangerously in other food cells and the biocides affect organisms for which it was harmless at the original doses.

From the widespread use of biocides for economic reasons (means and their application are financially demanding) also from environmental points of view (interest in the quality of the product without residues of various substances) it is transitioning to the **so-called integrated plant protection.** This includes, inparticular, the use of proven cultivation interventions (crop rotation - sowing practice), the promotion of natural enemies of pests (predators, parasities), the use of specific biochemical means (substances that disrupt the life processes ofthe pest) and, exceptionally, small doses of biocides, which decompose rapidly and act as specifically as possible. [55]

Intesification also affects **livestock production.** In it, there is often a high concentration of animals. The concentration of animals also entails the possibility of rapid spread of certain diseases and a number of negative effects on the surrounding environment.

Silage juices often pose **a danger to the surrounding environment.** Their spillage into waters usually means local ecological disasters - the death of fish and other organisms in streams and rivers. This situation occurs especially with less water flow. The main cause is a sharp decrease in the pH of water (increase in acidity) and an increase in the content of nitrogenous compounds.

The use of antibiotics and various hormonal preparations, the residues of which are then mainly found in milk **and meat,** is also a negative phenomenon in animal husbandry in livestock production. The production of greenhouse gases is a particular type of negative impact of agricultural production, which has not been much followed up to now. Agriculture, especially livestock farms, is the largest anthropogenic producer of methane. Methane is the second most important greenhouse gas in human production, with its so-called global warming potential (in the GWP world literature) 25 times greater than carbon dioxide (the most important greenhouse gas). [55]

Energy consumption in agriculture and in food processing and distribution is growing very strongly.

Limiting factors for agricultural intensification are the availability of water for irrigation and the amount of chemicals increasingly used to increase agricultural production such as fertilisers and biocides. The limits are given both in terms of soil quality (preservation of life and natural degradation processes in the soil), threats to groundwater and biodiversity, and in view of the need for a healthy diet for humans.

In the foreseeable future, it cannot be envisaged that the nutrition of the population will ensure agriculture without the use of chemicals. However, there are a number of good practices on how to reduce the risk of contamination of food with pollutants and reduce soil and water damage when using them.

The one-sided orientation of agriculture to the amount of production is also gradually beginning to change in our country and appropriate forms of alternative agriculture **are slowly expanding**. [55]

The understanding of alternative (organic) agriculture is not uniform and has a number of variants. For example, organic farming in Europe uses resilient and proven varieties and breeds, minimally uses fossil energy sources and raw materials, and applies only biological pest control. The so-called sustainable agriculture in the USA and Canada also recognises a certain proportion of agrochemicals, and so on.

In general, alternative agriculture should produce health-friendly food and raw materials for their production, maintain the natural fertility of the soil, naturally breed animals and protect environmental components.

So far, in industrialised countries, the area of "*alternative*" farmland managed is estimated at about 0,5 % (10 – 15 % in the outlook) and actual organic food production at about 1 %. Uniform standards are not yet developed to assess them, which would guarantee the consumer that the food is produced without the use of fertilisers, pesticides, growth regulators and various other additives. [55]

In summary, organic farming (often called alternatives) is in some ways returning to traditional farming methods, as it aims mainly at managing natural resources, respecting natural conditions, maintaining a balance in nature and the sustainability of food sou.

Organic farming is characterised in particular by the following characteristics [55]:

- **coexistence with natural ecosystems** (e.g. preserving part of natural ecosystems between fields - draws, meadows, etc.),
- **maintaining and developing soil fertility (in particular** the supply of sufficient organic matter to the soil and the formation of humus),
- **maintaining genetic diversity in both the plant and animal fields of agriculture (use of diverse varieties of plants and breeds of animals, rejection of dependence on** several growing overly demanding forms of organisms),
- **reduction of environmental and health damage (prohibition of the** use of biocides and the use of soluble forms of mineral fertilisers),
- **ways of caring for livestock commenced with their** physiological needs (in particular the rejection of industrialized large-scale animals),
- **purposeful use of ecological relations to increase agricultural production (taking care of the best possible course of biological cycles in the** agricultural ecosystem - agro-ecosystem, soil flora, fauna and microorganisms),
- **saving non-renewable resources** (in particular energy sources) and replacing them with renewable and inexhaustible resources (use of solar, hydro, wind, etc.),
- **landscape care** (ensuring anti-erosion measures by maintaining limits, limiting the area of field hons, etc.),
- **use of local food** sources (limiting food losses in their movement and saving energy in their storage and transport).

Binding rules have already been developed in a number of countries for organic farming methods, compliance with which is also controlled and the products of this agriculture are then called **organic products.**

5.3 Wood and Other Renewable Resources from Living Nature

From living nature, very important raw materials are used as renewables in various industries: **wood, various** natural fibres (cotton, wool, flax, etc.), **rubber, medicinal herbs, hides, furs.**

The biggest raw material problem **is wood** (Fig. 36). Its **overex exploitation threatens** forests all over the planet. More than 2,5 billion m^3 is spent annually in the world, of which about 40 % is used in construction, furniture manufacturing, etc., 20 % for paper production and the rest is burned [55].

Forests represent large areas of landscapes predominantly planted with trees (Fig. 37) and other plants. Currently, they cover about 30 % of the surface of dry land from the original 60 %. The largest trees are also the heaviest and longest-living organisms on Earth.

There are three basic types of forest:

- **coniferous forests** (colder areas of Canada, Europe and Asia, e.g.: spruce, edible, pine), **25 %,**

- **deciduous forests** (slightly warmer areas of the USA and Europe, e.g.: oaks, beech trees, poplars), **21 %,**
- **tropical** (rainforests) forests **(Brazil and Indonesia,** e.g.: ebony, mahogany), **54 %.**

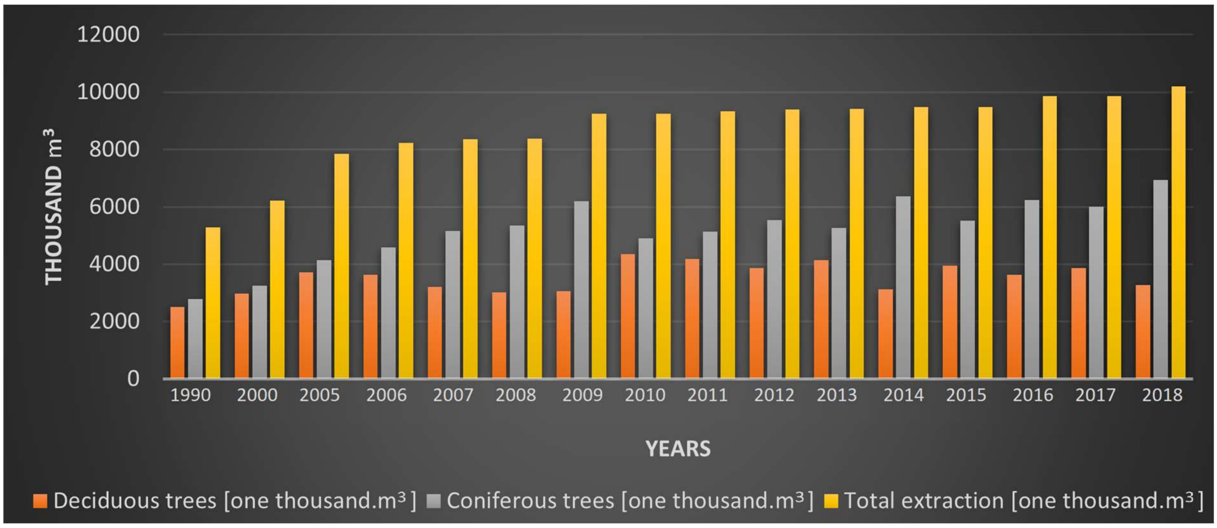


Fig. 36 Development of logging in the Slovak Republic since 2018 and reasons for logging [58]

In many countries, consumption is higher than its natural increment. In China, for example, consumption exceeds the annual increase of about 100 million m^3 per year, in India the annual increase in wood mass exceeds up to 7 times, and in Canada, while mining in some areas exceeds wood increments by 30 % [55].

Logging in tropical forests, ecosystems that have **evolved on Earth** for tens of millions of years, is a very serious problem. There were about 800 million hectares of tropical forests on Earth in 1990, including 330 million in Brazil. About 17 million hectares, or 2,1 % of the area, were extracted per year. For a better idea of the intensity of tropical forest felling, let us note that about 50 ha is lost about every minute. If logging continued at the same rate, Brazil's tropical forests would be mined in less than 50 years. [55]

The causes of the rapid destruction of tropical forests are different. Part will become more difficult for valuable wood, most for obtaining land for pastures and fields. In Brazil, the pasture thus obtained breeds cattle, which are exported for burgers to the USA, so that Brazil can pay the debts. In tropical areas there is a very fast cycle of substances, and the soil forms only a thin layer (usually up to 45 cm) covered by forest protection. After removing the trees, the soil dries quickly, depletes and the desert is boarded in place of the forest. Shepherds move on. Similarly, poverty is the main cause of the same destruction in Colombia, Madagascar, the Philippines and Africa.

Along with forests, other natural resources are disappearing - **herbs and animals** (Fig. 37) [55], many of which we do not even know yet and do not know how man could use them. It is estimated that in tropical forests, which cover about 7 % of the Earth's surface, about 50 % of all species of organisms live. This example shows the necessity of very consistent nature conservation. [55]

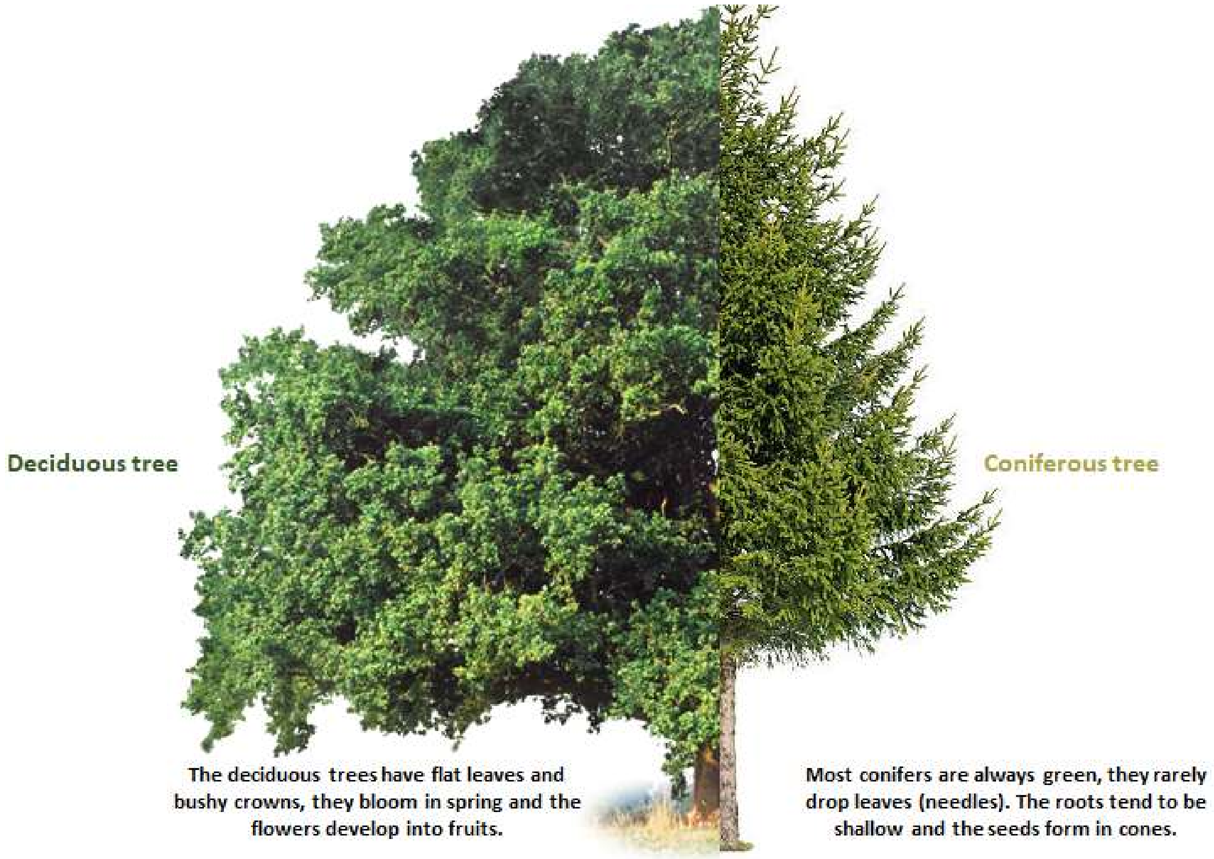


Fig. 37 Tree species

In addition to logging, forests **are also threatened by polluted air and acid rains.** In Europe, almost three quarters of forests are more or less affected in this way.

Reducing the need for wood would only allow for savings and much greater use **of recycling (e.g.** in paper production). At present, recycling in the world is at a very different and generally low level. It is reported, for example, that the USA has the largest paper consumption (317 kg per person per year) and so far only around 30 % is recycled. More than 50 % of paper is recycled in Japan. [54]

Another way of limiting logging from natural forests is to convert part of forests into high-yield forests, while other forests could be preserved as home to many plant and animal species. [55]

Forests cover 40,6 % of the total area of the country in Slovakia. **The composition** of forest trees (Fig. 38) differs significantly from the original composition of forests. Forests that are at least close to the originals are often nature reserves today. Most forests have been changed to multicultural areas, especially spruce, pine and popers. Only in recent decades, after the difficult experience of damaging such forests with wind, icing and subsequent pest infestation, has efforts been made to enrich the species composition (Fig. 39) and, at least in part, to pass through a forest mixed, which better corresponds to Central European conditions. However, some economically important species of plants are still preferred – beech trees (over 30,1 % of trees in forests), pine (7,1 %), rake (5,7 %), others significantly less. [54]

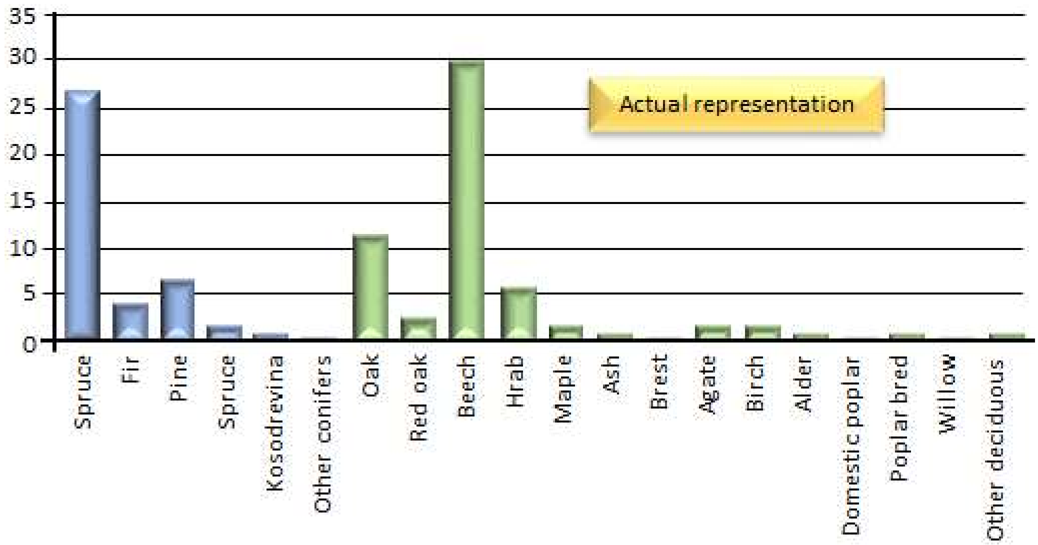


Fig. 38 Species composition of forests in Slovakia

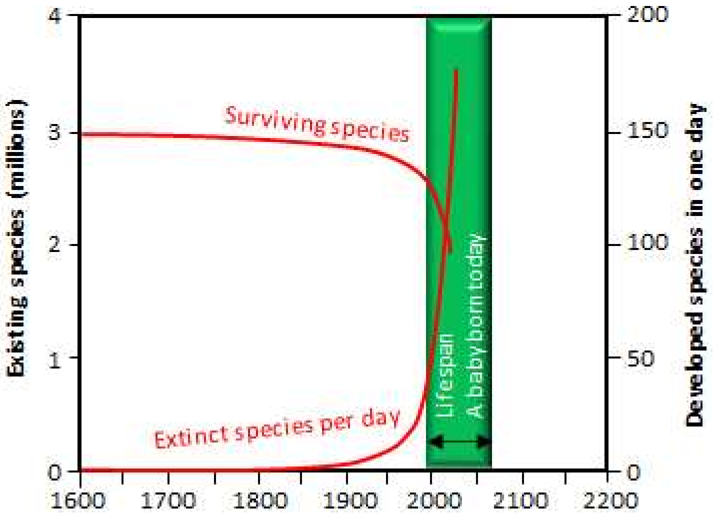


Fig. 39 Projected decline of species of organisms

In terms of importance (functions), forests are divided into [1]:

- **economic** (intended mainly for logging, more than 66 % of forests in our country),
- **protective** (in particular, the anti-erosion and water management function is valued, almost 15 %),
- **special purpose** (e.g. suburban for recreation, around the spa protection of underground water sources, more than 17 % of our forests).

Farm forests are mainly intended for **the reproduction of wood.** The principle that as much wood as the wood mass approximately grows from the forest must be maintained.

However, forests have less important **non-production functions** [11]**:**

- **the climate function is that forests hinder airflow (similarly scattered greenery in the landscape** - stromorodia, windtrolams, greenery on the limits, shore greenery, etc.), increase air humidity (especially in summer) as they capture so-called horizontal precipitation (fog, frost and, in connection with this, reduce temperature fluctuations),

- **hydric, water management and erosion function is related** to the fact that forests reduce surface run-off of water and water vapor. Water in the forests seates into the soil and moves through the so-called sub-sub-peak runoff, which is much slower,
- **hygienic - health and recreational function consists** in the beneficial influence of the forest on the health and psyche of man. Forest air tends to be the purest (it mainly captures solids - dust, aerosols) and enriched with various aromatic substances secreted by plants. These substances respond well with ozone, so there is few ground-level ozone in forests. Compared to its surroundings, the forest has a lower temperature and higher relative humidity and ionization. In forests, the green and yellow parts of the sun's spectrum predominates. They have peace of mind, natural sounds and aesthetic smings are very beneficial. Forests are home to many animals, they are the protection of biodiversity. Their edges (ecotones - places of contact of different ecosystems) are the species richest communities.

The future of forests depends on proper management and on the value of their importance for life in nature and for man. [11]

5.4 Minerals and Rocks, their Extraction

Minerals and rocks are essentially **non-renewable** natural resources, although some of them (rock salt, granite, basalt) are rather inexhaustible due to their expansion (from today's point of view). Currently, about 60 different rocks and minerals are mined. A distinguishing between [59]:

- **ores** (metal sources),
- **non-metallic raw** materials (gravel, stone, limestone, etc.),
- **causobiolites, i.e. fossil fuels** (coal, gas, oil, flammable shale).

These are unevenly distributed concentrations of elements and compounds that have arisen during long geological development. Most minerals are used by man in industry and are therefore essential for the smooth running and development of economic life. [59]

The global problem of mineral resources lies in their exhaustion and environmental interventions in their extraction and processing. Currently, about 25 billion tons of minerals a year are produced on Earth. However, the extraction of mineral resources in any form cannot be possible without interference with the environment. The extraction of minerals and the related development of industry, construction, transport and agriculture constitute human intervention in the lithosphere, resulting in disruption of the water regime and changes in geochemical and geomorphologic. Their impact changes the whole country in height, climate and hydrologically, thus conditioning the emergence of new landscape habitats.

The extractive industries are changing the original environment more or less permanently, as each mineral deed is non-renewable and irreplaceable after extraction. Thus, any extraction of mineral resources results in a change in the environment.

According to the method of economic use, mineral resources are divided into [60]:

- **energy raw materials** - coal, oil, natural gas, uranium, thorium, ...,
- **metallurgical raw** materials - iron, copper, tin, ...,
- **chemical raw** materials - salts, sulfur, phosphates, limestone, asbestos, ...,
- **building materials** - stone, gravel, sand, marble, granite, ...

According to economic importance, resources are allocated to [60]:

- **balance sheet** - these are proven sources of useful mineral resources, which meet the technical - economic criteria for efficient extractionand processing,
- **non-clanscent** stocks - sources of improperly stored raw materials with a low content of useful component, small scale, low power. Resources are only estimated.

According to the average content in the Earth's crust, the sources of elements are divided into [60]:

- **widespread** - (silicon, aluminium, calcium, magnesium, potassium, ...),
- **medium spread** - (carbon, phosphorus, manganese, sulfur, ...),
- **not widespread** - (flora, chromium, nickel, lead, copper, ...),
- **slightly widespread** - (tin, tungsten, ...).

Mineral extraction is a process by which useful or valuable substances such as coal, gas, salt, minerals or ores, gemstones or building blocks are obtained from the ground.

Sometimes mines were built to look for useful metals suchas lead, copper, iron and tin, but also precious metals. As the methods for drainage and for supplying miners with air were not effective, the mines were built at the surface. Over the last two centuries, these problems have been solved using machines. Today, mines can dig deep into the ground. Machines are used not only for water pumping and air exchange, but also for drilling and felling of sloys, for transporting people and equipment to mines and to the surface. [59]

There are many different methods of extraction (Fig. 40) - their choice is usually determined by thepom and depth of the bearing. Materials such as stone, gravel and sand are mined in quarries. Ore and minerals are extracted close to the surface in surface mines by means of mechanical excavaters or by strong water pressure. Deep bearings shall be made available by drilling a vertical shaft or tunnel into the rock. This method is called extraction by a horizontal corridor or ad at the ad. Explosives are used to build them. [59]

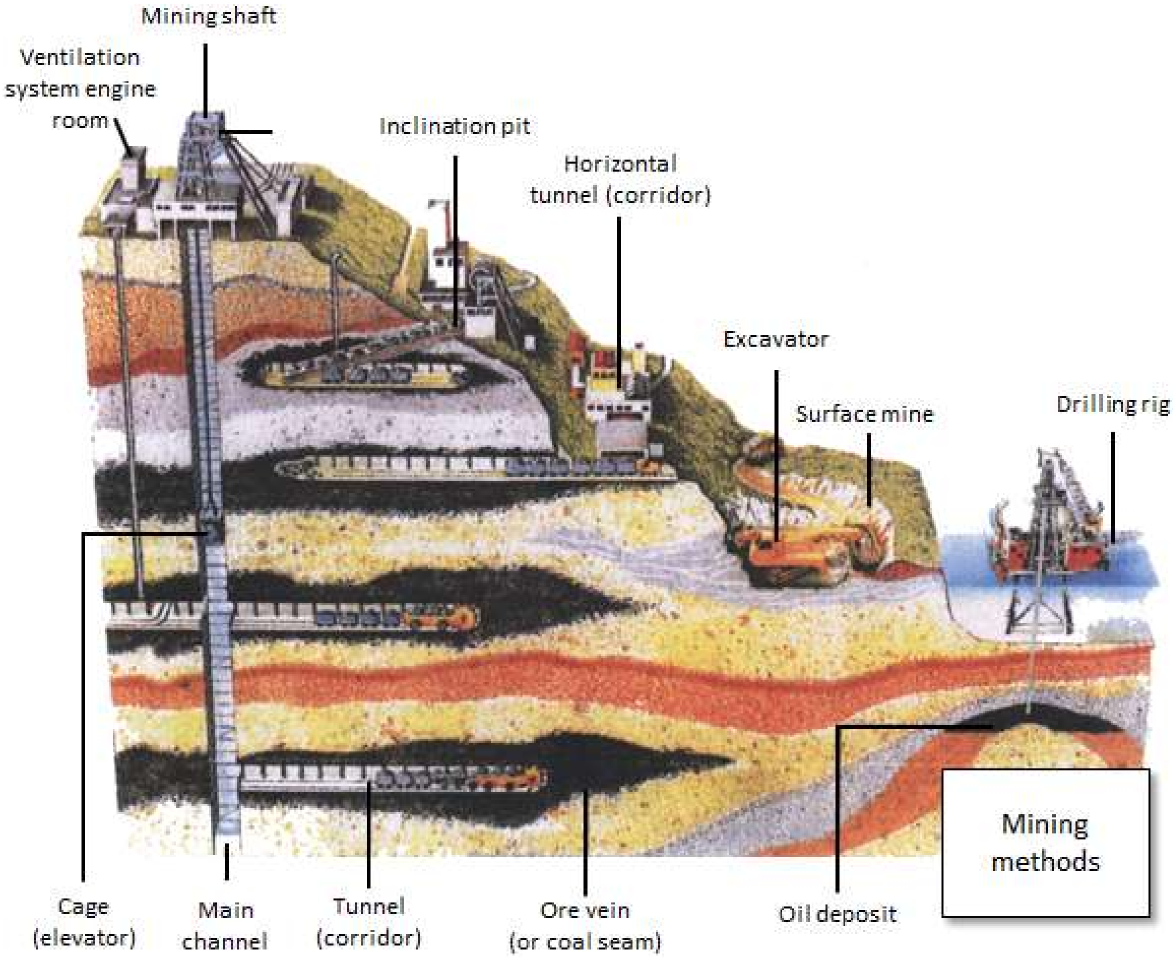


Fig. 40 Methods of extraction of mineral resources [11]

The Slovak Republic is rich in certain types of mineral resources (Tab. 4), but lacks large quantities of such serious raw materials as oil and natural gas (we have an incomplete domestic raw material base from the point of view of the processing industry).

Tab. 4

Review on reserves and mining output of mineral fuels in Slovakia in 2012 [61]

Mineral fuel	Anthra-cite [kt]	Bituminous rocks [kt]	Combusti-ble natuaral gas [kt]	Brown cool [kt]	Lignite [kt]	Crude oil non-paraffinic [kt]	Crude oil semi-paraffinic [kt]	Urani-um [kt]	Natur al gas [Mm^3]	Underground natural gas reservoirs [Mm^3]
Nr. of depo-sits	1	1	9	11	8	3	8	2	36	13
-exploite	0	1	2	4	1	1	4	0	12	2
Geological reserves total	8 006	10 793	394	463 706	618331	3 421	6 341	9 303	224 480	6 510
-economic verified -potentialy	0 5 998	6 682 0	149 194	58 147 304 345	89 997 340017	7 1 829	126 6 215	2 328 3 876	5 472 15 742	3 328 3182
Mining	0	2	2	1 964	136	1	11	0	93	13

5.4.1 Ore

Minerals from which various substances are obtained, mostly metals, are called ores. Their extraction has a very significant impact on both the environment and the natural environment. Iron ores are mined the most, aluminium ores are in second place. The growth of ore extraction and the estimation of the exhaustion of their stocks are given in Tab. 5 [55].

Tab. 5

Growth in ore extraction and an estimate of the exhaustability of their stocks [62]

Metal	Production 2000 (million tones)	Assumption 2100 (million tones)	Exhausted 2100 %
Iron	480	1900	55
Aluminium	17	120	Negligible
Manganese	8,7	40	18
Copper	8,1	40	almost everything
Zinc	6,4	22	37
Lead	3,2	22	75
Chromium	3,2	15	almost everything
Titan	1,7	8,6	38
Nickel	0,71	8,6	35
Tin	0,25	0,69	almost everything
Molybdenum	0,1	0,63	5

However, **opinions on the exhaustiveness of** ores are constantly changing, mainly for the following reasons [62]:

- New sites are still emerging, in the future it is assumed the possibility of obtaining various chemical elements from seawater - it contained about 79 chemical elements, from the seabed - manganese, cobalt, phosphorus, etc.
- Ores are used more efficiently **due to new** technologies - e.g. if 150 kg of copper wire has previously been produced from one tone of raw material, 120 000 km of optical fibre can now be produced from this raw material for information transmission.
- With raw materials, recycling is saved and **used** (iron is recycled more than 42 %, copper around 20 %, lead about 15 %).

Ores are extracted in surface and deep mines and very often also chemically. Since, with the amount of ores, mining is already economical at a content of 1 % metal, large heades and heades of tailings are usually formed, containing a large amount of heavy metals and residues of toxic chemicals after treatment of ores, e.g. cyanides. In particular, the dispersion of lead, mercury, cadmium, selenium and chromium in the environment is very dangerous, since these metals and their compounds are highly toxic [62].

At present, there are not major concerns on a global scale about the rapid depletion of natural resources any time soon. Other metal sources are not only in newly discovered deposits, but above all in that ores are extracted poorer in metal content, from which metals were not obtained for technological reasons some time ago and technologies that use other materials are gradually being promoted [62].

5.4.2 Non-ore Raw Materials

Non-metallic raw materials are mainly used in construction, both directly (stone, gravel) and for the production of building materials (cement, lime), etc. These substances are extracted the most globally - their annual volume is estimated at 12 billion tones. In our country, the extraction of these substances comes first. Significant are the extraction of brick raw materials, building stone and gravel, limestone. Building blocks and gravel are mostly consumed in the Republic, and it can be said that their production has declined in recent years. By contrast, limestone extraction persists at a high level and is widely used for exports - e.g. limestone indicates that 40 % of the cement produced is exported. [63]

Quarries, sandboxes, gravel sites in which these raw materials are harvested occupy large areas of land, often agricultural, disturb groundwater, degrade them and change the overall appearance of the landscape (Fig. 41).

Fig. 41 Sand mining [64]

They also intervene many times in protected landscape areas. Some quarries and treatment rooms interfere with, for example, the PYD Of the Little Carpathians and the national scoops of Malá and Veľká Fatra.

5.4.3 Fossil Fuels

Fossil fuels are non-renewable natural resources that are used as energy sources or in the chemical industry primarily for the production of artificial substances. [10]

Fossil fuel extraction is second only to building materials worldwide. Their approximate annual production in the world is shown by the figures shown in.

Tab. 6
Annual mining in the world 2021 [65]

Country	Consumption of fuel [kWh]
United States	63,130
Australia	53,644
Germany	31,647
Europe	29,928
China	25,081
United Kingdom	22,303
South Africa	21,796
France	19,9106
India	6,326

Source: Our World in Data based on BP Statistical Review of World Energy

It is usually mined to a depth of about 100 m, sometimes more than 300 m, which is associated with the movement of huge volumes of matter.

Fossil fuels are mainly used for the production of electricity, thermal energy and propulsion of motor vehicles. For these purposes, it is relatively easy to adapt them, but they must be transformed before possible. [1]

The great advantage of using fossil fuels is that converting them from raw to energy is simple and inexpensive. The downside is that natural resources are rapidly depleted and spent, with the possible consequence of land decline. A major disadvantage is that when fossil fuels are burned, pollutants that have serious negative impacts on the environment, e.g. acid rain formation, smog, increasing greenhouse gas concentrations in the atmosphere, contribute to the reduction of the ozone layer. The most important fossil fuels are: coal, oil and natural gas. [10]

Coal originated in various geological times by the so-called charcoal of accumulated plant residues without air access, at high temperature and high pressure of overladen layers. In the primorlands of cambria and perm (about 300 million years ago) charcoal was formed from prehistoric gilts and floats, in the third mountains (about 60 million years ago) brown coal was formed from nasty plants (Fig. 42). For the idea of differences in lignite and hard coal: the calorific value of 1 kg of hard coal with a sulphur content of about 1 % is about 34 MJ and the calorific value ofquality lignite with a sulphur content of 1,5 to 2 % is approximately 17 MJ. The calorific value of lignite mined in Slovakia (Area Handlová – Nováky) is 12 MJ or less. The calorific value of the lignite (theyoungest in the movement mined around Holíč) is about 9 MJ. Coal is extracted at 50 % surface, 50 % in deep underground mines. [11]

Surface mining - mainly brown coal allows to extract coal deposits.

In our country, lignite mining is currently concentrated around Novákov, Prievidza and mining around Veľký Krtíš has been stopped.

Deep-sea mining - mostly hard coal, which can be extracted to 50 % in this way, also changes the character of the landscape - by emptying, sinking the soil in undersized places, flooding the sinks with water.

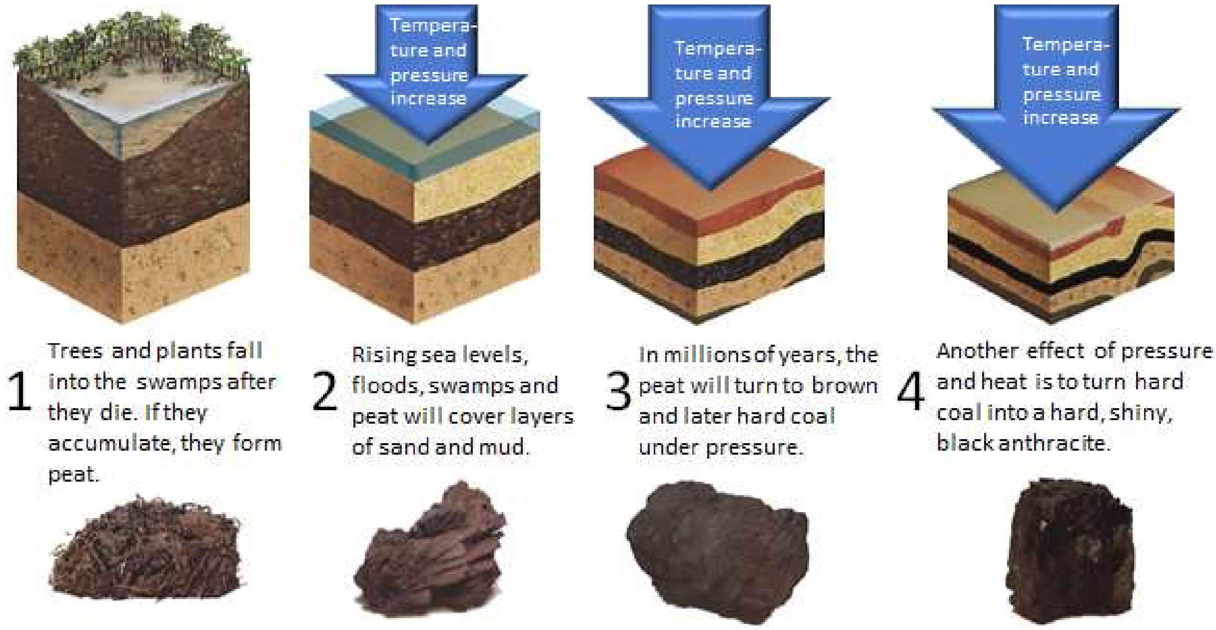


Fig. 42 Coal generation process

Coal mining is on a downward trend here. In 1992, just over 3,5 million t were extracted, compared to 5,8 million t in 1983 and 4,8 million t in 1990. After the government's measures, mining with small fluctuations stabilised after 1993 (Fig. 43).

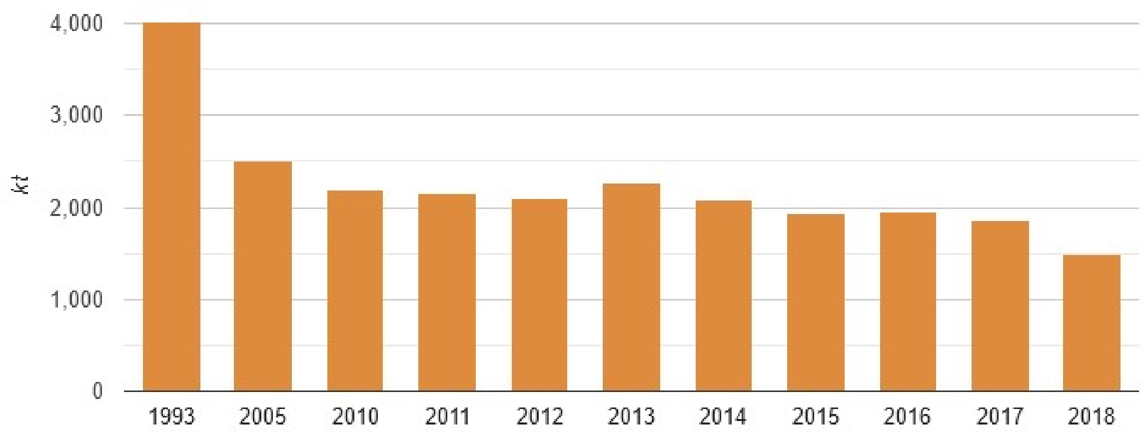


Fig. 43 Development of coal mining in Slovakia [66]

Petroleum

The remains of plants and animals that have lived on Earth for millions of years form the basis for oil as we know it today. It is a mixture of liquid hydrocarbons with variable values of oxygen, nitrogen, sulphur and heavy metals. The color can vary from golden brown to ebony black. It's also called "*black gold*". [67]

Oil reserves lie thousands of meters below the surface of the earth and are sought with seismological research. The pressure measures the lower part of the layer of the earth to see if there is oil in the place. The size of the deposit will also be measured to determine whether oil production at a given location will be profitable. [67]

Crude oil is surfaced by drilling rigs (Fig. 44). It is transported by ship or pipeline to oil refineries. There it is switched to fuel such as gasoline, diesel, kerosene and liquid fuel, but it is also used for the production of organic substances, plastics, asphalt, tar macadamia, paints and washing powders.

Fig. 44 Oil tower in the sea [67]

As a natural resource, oil is much more valuable than coal, above all it is more versatile - relatively easy totransport (oil pipelines, tankers, tankers) and has therefore become a global fuel. Its extraction is rapidly developing and locating to the Gulf, North Africa, the Gulf of Mexico, the Caribbean Sea, the North Sea, Western Siberia and Southeast Asia (Tab. 7 and Tab. 8). More than 1/2 of the oil extracted is exported to the USA, Japan and Western Europe. OPEC member countries export the most from the Gulf regions.

Tab. 7

Oil production per capita, 2021 [68]

Country	Consumption of fuel [kWh]
Kuwait	352,221
United Arab Emirates	191,345
Saudi Arabia	169,485
Canada	81,600
Russia	42,758
United States	24,842

Source: BP Statistical Review of World Energy: the Shift Project

Oil is the most widely used energy raw material. As a result of rapid population growth and well-being, oil consumption worldwide has increased. Political developments in the 1970s shook the oil market. This led to the oil crisis of 1973, which continued in 1974. Since then, the price of oil has risen significantly. OPEC (Organization of the Petroleum Exporting Countries), established in 1960, plays an important role in determining oil prices. Oil reserves of OPEC countries make up 80 % of global inventories.

Tab. 8
Per capita oil consumption, 2021 [68]

Country	Consumption of fuel [kWh]
United States	29,476
Australia	20,798
Norway	19,213
Chile	10,585
United Kingdom	10,165
China	5,885
Brazil	5,785
South Africa	4,816
India	1,875

Source: Our World in Data based on BP Statistical Review of World Energy & UN Population division Our World InData. Org/energy. CCBY

There are enough oil reserves for the next decade, but they are rapidly running out in the long run. In the short term, the use of oil has a great impact on the environment and, finally, we will have to replace it with another, more environmentally friendly type of energy.

Natural gas

Natural gas as a fossil fuel played a significant role in the second half of the last century. It was the last fossil fuel discovered and, like coal and oil, was created from the remnants of fossils of plants and trees over millions of years.

The term natural gas is a common name for more fossil gases that can be used as fuel [1]:

- **coal gas** - produced when coal is created,
- **petroleum gas** - it arises from oil under the influence of temperature and pressure.

Natural gas is sought in the same way as oil, namely by seismological research of the earth. During the test wells, it shall be determined whether it will be advantageous to benefit from a particular gas field. Most natural gas reserves are located in **the Middle** East, **Russia** and Europe (North **Sea**).

Natural gas reaches the surface using drilling rigs. Much of the natural gas consists of hydrocarbons such as propane, butane and methane. There are also other gases such as nitrogen, carbon dioxide and helium. Natural gas is transported by high pressure pipes to users.

Natural gas shall be mixed with other gases before distribution and according to consumer requirements, producing [10]:

- **low-calorie gas** - is used by ordinary consumers,
- **high - caloric gas** - is used by large industrial plants and power plants.

The caloric value measures the heat produced by combustion and is important for all natural gas installations.

The disadvantage of natural gas is that it is invisible, spreads quickly and is explosive. On the other hand, it is inexpensive, easy to transport and is the least polluting fossil fuel. The world's current gas reserves are also sufficient for the next decade, but in the long term these reserves are also being depleted. In the short term, natural gas, like other fossil fuels, has an impact on the environment and will ultimately have to be replaced by another more environmentally friendly energy source. [11]

Natural gas is the most economically advantageous fuel. Most often it occurs together with oil. Its occurrence is mainly concentrated in developed countries. The largest exporters of natural gas export gas through pipelines to Western and Central Europe, the USA and Japan (Tab. 9).

Tab. 9

Gas production per capita, 2021 [69]

Country	Consumption of fuel [kWh]
Russia	48,088
Canada	45,266
United States	28,061
United Kingdom	4,794

Fossil fuel extraction in the world continues to grow. However, new reserves are still emerging, e.g. in the seas, so there is no danger of depletion of fossil fuel deposits on a global scale any time soon.

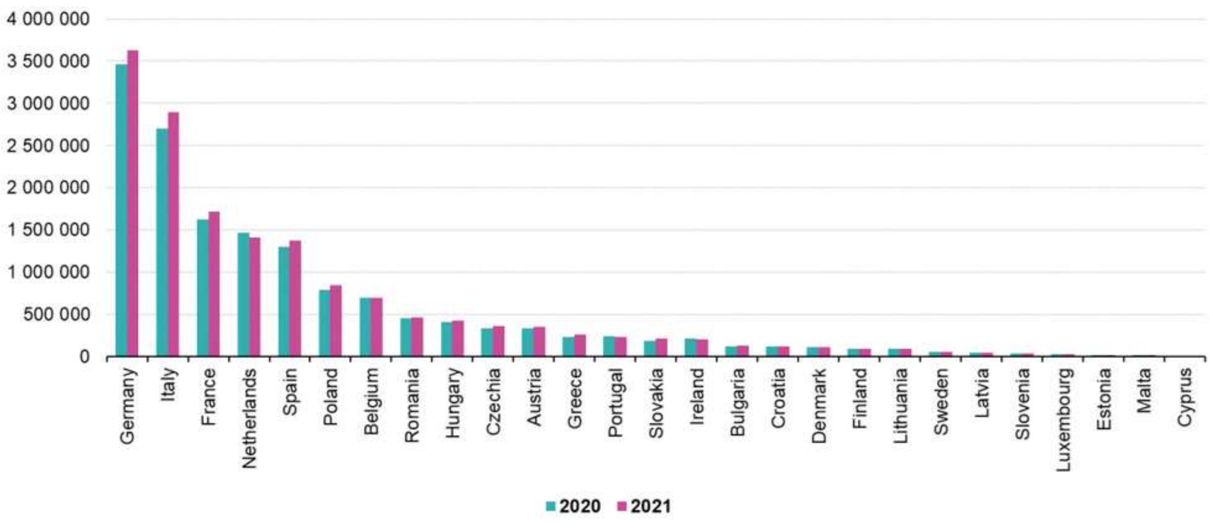


Fig. 45 Inland demand of natural gas, by country, 2020 - 2021 (terajoules (Gross Calorific Value)) [70]

5.5 Extraction and Processing of Critical Raw Materials for the European Union

In addition to its dependence on Russian gas, Europe also has to deal with dependence on imports of precious raw materials from third countries, in particular China. Germany and France presented the basic contours of a new law on critical raw materials to ensure more resilient supply chains [71].

In her State of the Union address on 14 September 2022, Commission President Ursula von der Leyen proclaimed the European Critical Raw Materials Act as one of the key legislative initiatives for this year, recalling that demand for critical raw materials is expected to grow 500 % by 2050 as a result of the green and digital transitions. This was based on the World Bank's forecast that demand for critical raw materials will skyrocket in the coming decades. Lithium and rare earths are expected to soon be more important than oil and gas. [71]

Many of the raw materials considered critical by the European Commission are mined or processed in China. The extraction of raw materials is currently dominated by only a handful of players, with China in particular having a monopoly in several sectors. For example, the European aluminium industry was threatened by a disruption in the supply of magnesia from China in 2021, as the EU imported 93 % of this raw material from there at the time. [71]

Critical raw materials are used not only in solar panels or wind turbines, but also in battery storage or electric cars. According to the International Energy Agency, an electric car consumes six times more of these raw materials than a conventional vehicle with an internal combustion engine (Fig. 46).

Fig. 46 Lithium mining in the Salinas Grande Desert, Argentina. [72]

Critical raw materials are crucial for the EU's green and digital transition. The importance of a stable supply of these critical raw materials for the overall strengthening of the resilience of European supply chains is extremely important. [71]

The EU's two largest economies (Germany and France) underline the need and importance of adopting a law on raw materials and outlined their vision of what the new law should bring.

According to the aforementioned pair of states, the draft law should include three pillars: an early warning system and a crisis management mechanism for critical raw materials, support for investment in production and recycling, and ensuring a global level playing field.

The Franco-German proposal stresses the need to create a sovereign investment fund in order to attract finance to mining, refinery, primary processing projects with an emphasis on the circular economy. [71]

The first two pillars are similar to the European Chip Law proposed by the Commission in February and address a similar issue: increasing the resilience of semiconductor supply chains.

This could mean relaxing some state aid rules under its main subsidy scheme – **I**mportant **P**rojects of **C**ommon **E**uropean **I**nterest (**IPCEI**) – in order to increase investment in the mining sector. [71]

However, the forthcoming law on critical raw materials will not only concern security of supply. It also aims to reduce dependence on China for the refining of raw materials.

One example is lithium, which is a key component of batteries and is therefore essential for the green transition. While only about 9 % of the world's lithium is mined in China, around 60 % is processed there. This further expands the EU's range of dependence on China.

Similarly, cobalt is mined primarily in the Democratic Republic of Congo, but China is a global leader in its further elaboration. China's lead in raw material processing is even greater than in the case of physical concentration of stocks. [71]

However, Europe's efforts to gain its share of the market for critical raw materials will not be without hindrance. The exponential growth in demand favors players who have already reached monopoly positions in the extraction of raw materials.

Mining in Europe is expected to expand. There is a need to invest in the whole aspect of the circular economy and recycling. And supply chains also need to diversify. [71]

All these changes bring new challenges. While the European Commission has already made recycling a priority in both the Batteries Regulation and the new Packaging Directive, it is believed that it will not be sufficient to meet the exponentially growing demand.

The same applies to mining in Europe. While the continent has considerable resources in terms of certain raw materials, such as lithium, the process of obtaining mining permits can take years and often meets with resistance from local communities. [71]

One example is Portugal, which has the richest reserves of lithium in the EU. The country wants to open a new lithium mine, which has met with considerable resistance from local communities and NGOs. The approval process for the exploration of "white gold", which is an essential element in the manufacture of batteries, has been dragging on for years (Fig. 47).

Fig. 47 Gold mining at the Kumtor mine in Kyrgyzstan. [74]

While Europe's dependence on Russian energy is in the spotlight, the Union has an increasing interest in reducing imports of critical raw materials from third countries. The main problem is China's monopoly position.

At present, the European Union is almost entirely dependent on imports of critical raw materials from third countries. These are metals and minerals that are crucial for the production of electronics, green technologies and also in electromobility. [73]

The issue of strengthening the bloc's strategic autonomy in the raw materials sector has been high on the Brussels agenda, with a number of legislative proposals addressing this issue.

The aim is to ensure that the EU's strategic dependence is reduced. The green transition based on digitalisation is simply not possible without secure access to raw materials.

The extraction of raw materials is currently dominated by only a handful of global players, with China having a monopoly in several sectors. Dependence on one supplier became more visible in 2021 when China curtailed the production of magnesium, which is a key alloy for the aluminum industry. The supply disruption had a significant impact on Europe, as it was importing 93 % of magnesium from China at the time.

"It is unsustainable for the European economy to be more than 80 % or 90 % dependent on one country," EIT Raw Materials CEO Bernd Schäfer, who was tasked with managing the European Raw Materials Alliance, told EURACTIV. [73]

This is especially true for countries such as China, where "dumped prices and unequal conditions have made it possible to build a monopoly in this segment.

The demand for raw materials is currently growing exponentially. According to World Bank forecasts, demand for high-impact minerals such as graphite, lithium or cobalt will increase by 500 % by 2050. [73]

As most of this increase comes from energy storage technologies, striving for greater strategic autonomy is also a prerequisite for enabling "decarbonised and digitised economies." The transition to clean energy means moving from fuel-intensive to mineral-intensive systems.

However, Europe's efforts to gain its market share are not without hindrance, as the exponential growth in the need for scarce raw materials is likely to benefit players who have already reached monopoly positions in their extraction. There is a growing risk of the EU becoming more dependent as a result of this exponential growth in demand.

The European Union must act on several fronts at the same time. Firstly, mining in Europe must be expanded. Secondly, the whole aspect of the circular economy and recycling must be invested in. And thirdly, supply chains need to be diversified. [73]

All these changes come with their own challenges. While the European Commission has already made the sourcing of raw materials through recycling a priority in its Battery Regulation and the new Packaging Directive, recycling alone will not be sufficient to meet the exponentially increasing demand. [73]

The same applies to mining in Europe. In addition to new jobs and a "secure and sustainable supply of raw materials", mining in Europe is also expected to bring "responsible sourcing and processing of raw materials". [73]

This is because the European Commission is counting on Member States to check compliance with high environmental and social standards in accordance with European legislation when opening new mining sites. [73]

While the continent has considerable resources when it comes to certain raw materials such as lithium, the process of obtaining mining permits can take years and often meets with resistance from local communities. One example is Portugal, which has the largest reserves of lithium in Europe, an essential element in the production of batteries.

Although the state has given the green light to mining, the local government has already announced that it will file a court action, delaying the project. [73]

The lithium mining project of the British-Australian company Rio Tinto, which wanted to mine lithium in Serbia, also met with protests. An amendment to the law on expropriation, which was eventually withdrawn from parliament by the Serbian government, was supposed to pave the way for him. The intention to mine in Serbia sparked nationwide protests, and Serbian President Aleksandar Vučić stopped the project at the end of last year. [73]

In September 2022, the European Commission presented **an action plan on critical raw materials. It foresees that Europe's climate and digital ambitions will lead to a sharp increase in demand for critical raw materials. The solution should be to reduce dependence on their imports, develop mining in Europe and recycle more efficiently.**

The COVID-19 crisis has prompted the European Union to take a critical look at its dependence on imports of precious raw materials. Indeed, some valuable primary raw materials are imported from only one country, and this increases the risk of their supply being interrupted. [74]

A secure and sustainable supply of raw materials is a prerequisite for a resilient economy. It would be a strategic mistake to replace the current dependence on fossil fuels with dependence on critical raw materials. [74]

Precious raw materials are the basis of "green technologies" such as solar panels, fuel cells for electric vehicles or wind turbines of power plants. Since critical metals and minerals are part of electronic devices, such as smartphones and tablets, they are also an essential prerequisite for the development of digitalization. This is to be one of the pillars for achieving the European Union's climate objectives. [74]

One of the aims of the action plan is to identify and exploit domestic resources of scarce raw materials. It is a priority that coal regions in the EU, in particular, are reoriented towards this area of mining. According to the map with deposits of valuable raw materials presented by the European Commission, EU countries are already strategic suppliers of some precious raw materials (Fig. 48).

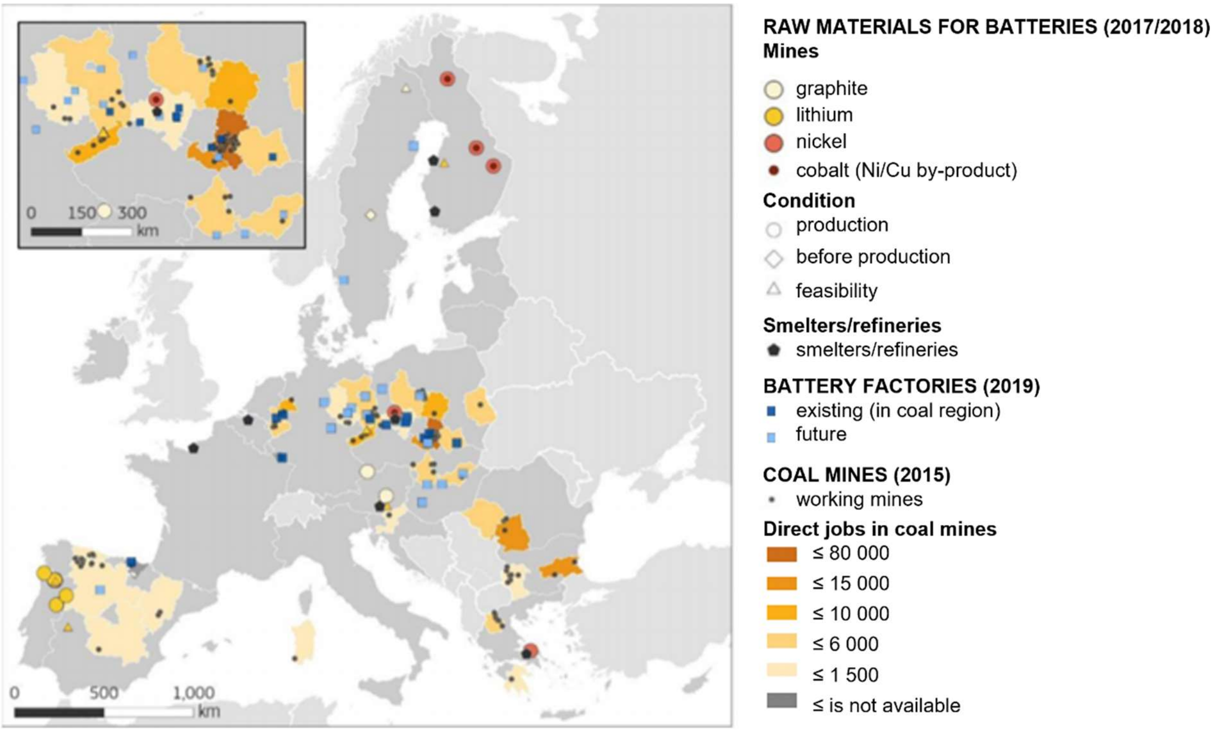


Fig. 48 Battery raw material extraction mines, battery factories and coal mines [74]

Strontium is mined in Spain, hafnium, indium in France and nickel in Finland (Fig. 49). Germanium deposits are in Finland, gallium is mined in Germany. This year, lithium, whose deposits are located in the Czech Republic, France, Portugal and Spain, has also been included in the list of rare raw materials. [74]

Fig. 49 The Talvivaarana mine in Finland is the largest nickel deposit in Europe [73]

The potential for extracting scarce raw materials is high in Europe, but little is being mined. According to the Commission, there are several reasons for this: a lack of investment, lengthy national permit granting procedures and the low popularity of mining among the indigenous population. [73]

Portugal and Finland are two striking examples of european mining taking off in style and the Commission wants other countries to catch up and help increase the Union's reserves.

However, the european environmental think tank European Environmental Bureau (EEB) has warned that increasing mining in Europe could be a double-edged sword. [73]

"Opening up new mining projects in Europe without sufficient control would run counter to the European Commission's ambition to keep resource consumption within planetary boundaries, as set out in the Circular Economy Action Plan in March," says Jean-Pierre Schweitzer of the EEB. [73]

According to the think tank, Europe should rather focus on reducing the use of scarce resources and preventing the environmental disasters often associated with mining, such as deadly pollution, water scarcity and the displacement of people. It is likely that the relocation of mining to Europe will mean environmental damage, which has been paid for decades by residents in South America, Asia and Africa, the EEB stresses in its opinion.

According to the environmental think tank, the opening of new mining projects in Europe should be subject to strict control and a thorough assessment of the environmental and social impacts on the local population. Local communities should be involved in a comprehensive consultation process in a timely manner so that they can comment on the project in a timely manner and, where appropriate, prevent it. [73]

Many sources of raw materials for batteries, such as lithium, nickel, cobalt, graphite and manganese, are located within the European Union in regions that are highly dependent on coal or carbon-intensive industries. In some of these regions, it is planned to build battery factories as part of a just transition and to preserve jobs after the coal downturn. [73]

In the document, the Commission says that new mining projects for valuable raw materials could become part of a just transition where the mining skills of former coal workers could be exploited. When drawing up just transition plans, Member States should "assess the potential of critical raw materials as one of the alternative business models and sources of regional employment". [73]

According to the Commission, waste from mining is also rich in critical raw materials, which could be processed "with the aim of creating new economic activity at existing or former coal mining sites while improving the environment". [73]

Europeans are largely reliant on raw materials that come from third countries in terms of technological development. They import antimony and borates from Turkey, palladium from Russia, phosphorus from Kazakhstan, cobalt and tantalum from the Democratic Republic of the Congo, niobium, iridium, platinum, rhodium and ruthenium from the United States, beryllium from the United States. The most precious raw materials, including vanadium, skandia, titanium and many rare earths, are imported into Europe from China. The largest suppliers of critical raw materials to the EU are listed in Fig. 50.

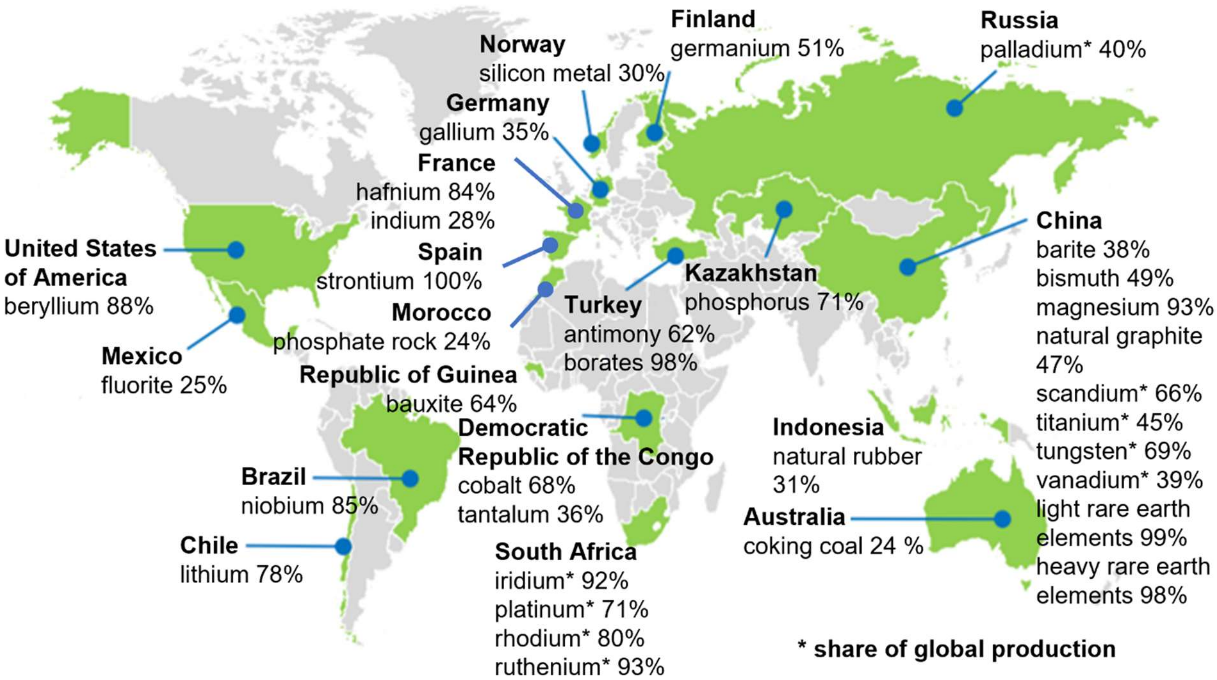


Fig. 50 The largest suppliers of critical raw materials to the EU [73]

The extraction of scarce raw materials is often concentrated in a small number of less developed countries. Development organisations have been warning for a long time that the deposits are located in conflict zones, where they risk financing armed conflicts. They are often associated with environmental damage, forced displacement and the use of slave labour.

The European Union will cooperate with third countries in obtaining rare minerals and minerals. This should be done sensitively and in the interests of the development of local communities. This means that the extraction of raw materials should respect ecological standards and human rights. [73]

It is assumed that the EU will have to focus much more intensively on Africa. According to him, mining should take place while maintaining the highest ecological standards.

"Europeans, if they want to drive an electric car, will expect that their car is made of sources whose extraction has respected environmental standards and human labour rights, that children have not been exploited for hard work," Šefčovič explained.

The Union is the largest donor of development aid in Africa and therefore has the levers to push for the raising of environmental standards in these countries.

First of all, the Union must step up cooperation at international level. The model may be trilateral cooperation with Japan and the US, in which they promote high environmental standards in the OECD. As a result, from 1 January 2022, new guidelines for member countries on how to deal with critical minerals will come into force in the OECD. [73]

International mechanisms will have to be sought to ensure open access to countries with important raw materials. This is the case, for example, with China, which is an important partner for the EU, but the EU is even more important to China from a commercial point of view.

Another way for the European Commission to meet the EU's growing demand for raw materials is to extend the lifespan of products and use secondary raw materials. In doing so, it refers to the New Circular Economy Action Plan. [73]

According to the document, the circular economy and the recycling of raw materials from low-carbon technologies are an integral part of the transition to a climate-neutral economy. Since the development of the circular economy, the European Commission has promised to increase jobs by 700 thousand by 2030.

Electrical and electronic equipment is one of the fastest growing waste streams in the EU, with its current annual growth rate of 2 %. It is estimated that less than 40 % of electronic waste is recycled in the EU. [73]

Of the metals, iron, zinc or platinum are the most recycled. The secondary use rate for these raw materials is up to 50 %.

The low level of recycling in the EU is for raw materials that are needed in renewable energy technologies or modern technology applications. For rare earth elements such as gallium or indium, secondary appreciation has only a minimal proportion. This represents a major loss for the EU economy, a source of avoidable burdens on the environment and climate.

That is why the Commission wants to come up with a proposal for a new comprehensive regulation in October 2022, which will also address reuse, collection, recycling efficiency and recovery of materials and extended producer responsibility. [73]

According to the European Commission, extensive monitoring of waste treatment can prevent precious raw materials from ending up in landfill. There is a lack of complete information on the amount of raw materials contained in products, extractive waste or landfills, i.e. raw materials potentially available for recovery or recycling. A significant amount of resources are exported from Europe in the form of waste and scrap, which can be recycled into secondary raw materials. The contribution of recycling to covering the demand for raw materials (recycling rate) is presented in Fig. 51.

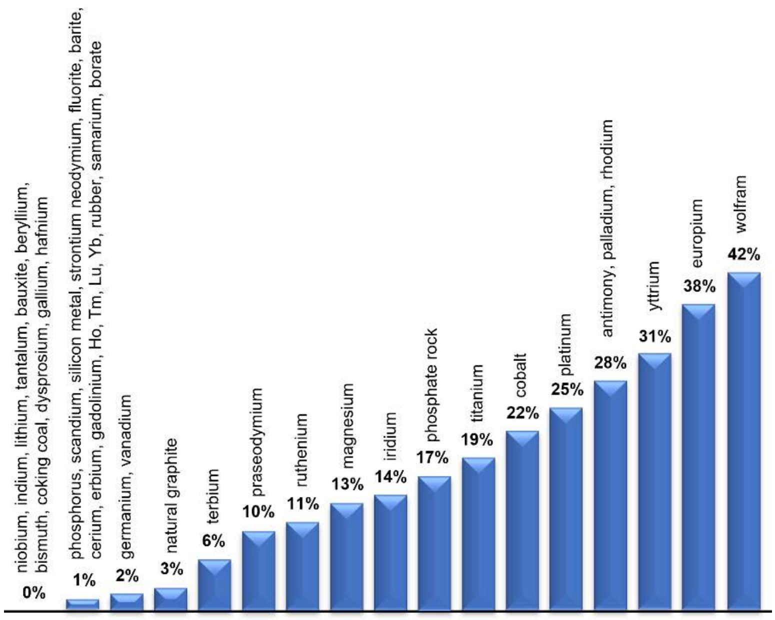


Fig. 51 Contribution of recycling to meeting the demand for raw materials (recycling rate) [73]

The demand for scarce raw materials is growing globally. The causes are population growth, industrialisation, the decarbonisation of transport, energy systems and new technologies. According to the World Bank, climate targets and efforts to keep global temperature below 1,5 °C above pre-industrial levels also contribute significantly to the need for precious metals and minerals. [73]

The inclusion of new minerals on the critical materials list has a major impact on EU policy-making, according to the EURACTIV.com portal. It influences the direction of trade policy and investment under the Horizon Europe research programme. It also influences broader industrial policy. [73]

The new list of critical raw materials is increased to 30 in the draft action plan, up from 27 in 2017. Bauxite, lithium, titanium and strontium were added to the list, while helium was removed "due to a decline in its economic importance" (Tab. 10).

Tab. 10
EU list of critical raw materials [73]

Critical raw materials from 2020 (new ones in bold compared to 2017)		
antimony	hafnium	phosphorus
barite	heavy rare earth elements	scandium
beryllium	elements of light rare earths	silicon metal
bismuth	indium	tantalum
borate	magnesium	tungsten
cobalt	natural graphite	vanadium
coking coal	natural rubber	**bauxite**
fluorite	niobium	**lithium**
gallium	metals of the platinum group	**titanium**
germanium	phosphate rock	**strontium**

According to EURACTIV.com, the inclusion of lithium is a clear signal for the rise of electromobility. This is expected to be key to achieving a reduction in CO_2 emissions and manufacturers are expected to step up production of new EV models in the coming years.

As part of the Action Plan, the Commission carried out a new analysis of what raw material needs the EU will have in 2030 and 2050, concluding that demand for lithium will increase 16-fold by the end of the decade and will be up to 60 times higher by 2050. [73]

Cobalt, which is also a key ingredient in batteries for electric vehicles and energy accumulators, will also see a surge in demand – a 50 % increase by 2030 and a 15-fold increase by 2050. [73]

Some battery manufacturers – especially Tesla – are trying to reduce or even eliminate the amount of cobalt needed in power supplies, given the cost of the material, the environmental impact of its extraction and human rights violations in the countries that produce it.

The sharp increase in demand for critical raw materials has also caused a sharp increase in the prices of these raw materials. Prices of selected raw materials found in lithium car batteries (LiA). [73]

Tab. 11
Material composition of LiA with respect to prices of individual compound [75]

Compound	Compound content [%]	2020		2021		2022	
		Compound price/t [US$] 2020	Compound price in LiBs [US$/t]	Compound price/t [US$] 2021	Compound price in LiBs [US$/t]	Compound price/t [US$]	Compound price in LiBS [US$/t]
Lithium (Li_2Co_3)	1(5,32)	8 000	426	24 800	1 319	80 250	4 269
Cobalt	3	33 965	1 019	55 755	1 672	82 000	2 460
Copper	9	6 810	613	9 860	887	10 200	918
Aluminium	35	1 744	610	3 076	1 076	3 214	1 125
Nickel	3	14 554	437	19 825	594	32 445	973
Manganese	3	1 667	50	7 520	225	7 039	211
Graphite	8	500	40	970	78	1 310	105
Steel	9	295	27	445	40	510	46
Plastics	11						
Volatile components	8						
Elecronics	3						
Wiring	2						
Total			**3 222**		**5 895**		**10 107**

5.6 Energy Resources, Fossil Energy

Man obtains energy sources from available, **so-called primary** energy sources, i.e. wood, water, wind, fossil fuels, uranium ore. Treatment and transformation produces noble forms of energy (electric current, gasoline, diesel, gas and others). **Wood** has so far served as the only source of energy for 1/4 of humanity. This causes gradual desertification in semiarid areas with huge negative ecological and social consequences [76]. At the beginning of the 19-th century, wood was replaced by more efficient sources of energy, **especially coal**, at the end of the century **also with diesel.** Coal reserves are estimated at 700 years. Proven oil reserves are for about 40 years, and importance is shifting to the area of the raw material base for the petrochemical industry. Most of the time, only waste products from the oil refinery are burned only in the form of heating oils. Heavy petroleum oils (mazut) contain a greater amount of sulphur, therefore the impact of combustion on the environment, especially the air, is similar to that of burning coal. In industrialised countries, the energy intensity of production is being lowered. Natural gas is an almost clean source of energy, well transportable, energy-efficient with minimal environmental impact. Stocks are similar to oil. Other fossil fuels include tar sands, flammable bituminous slates, whose reserves are significant on Earth. [76]

About 88 % of the world's industrially produced energy comes from fossil fuels. It should be borne in mind that fossil fuels are natural resources **exhaustible and non-renewable.** When burned, they change irreversibly completely - carbon dioxide and ash are produced. Given that fossil fuels are also a very valuable and irreplaceable raw material for the production of quantities of chemicals, their energy use must be regarded as a huge waste and irresponsibility towards future generations. The accumulation of carbon dioxide in the atmosphere contributes substantially to increasing the greenhouse effect. In addition, fly ash and other substances, in particular sulphur dioxide and nitrogen oxides, arise from combustion, pollute the air and cause acid rains. [76]

From the point of view of sensible use of fossil fuels, also in order to influence the Earth's climate, it would be necessary to reduce as quickly as possible the amount of fossil fuels used for energy purposes. In reality, however, it is quite the opposite so far. [76]

At present, more than 44 % of the electricity in conventional thermal power plants is obtained from coal on a global scale. In our republic, approximately 21 % of electricity is obtained from conventional thermal, i.e. combustion plants. A large amount of fossil fuels are also consumed in transport and heating in the form of various gasoline, oils, diesel and gas. [76]

5.6.1 Energy

Energy produces the necessary electricity for all sectors of the national economy and is therefore the basis for it. It belongs to the fuel and energy industry, which belongs to heavy industry. The energy product is electricity.

The establishments for the production of electricity from natural sources are called power **plants**. According to sources, four types of power plants are distinguished [76]:

- **thermal power plants,**
- **hydroelectric power plants,**
- **nuclear power plants,**
- **alternative power plants.**

Thermal power plants

Thermal power plants use oil, natural **gas and coal to generate electricity.** At the beginning of the 20-th century, it was coal that was widely used, which needed a large amount, so these power plants were located near coal mines. A large number of such power plants caused significant air and nature pollution, which is why over time in the second half of the 20-th century it began to switch **to the use of oil and natural gas.** These power plants are still the biggest air polluter. [76]

Hydroelectric power plants

Hydroelectric power became the most important source of energy for the development of industry in the early 20-th century, alongside fossil fuel energy. So far, about 30 % of the world's hydropower reserves are used. Electricity generation in hydroelectric power plants has several important advantages: it is inexpensive, flexibly responds to energy peak needs, does not pollute the environment. The disadvantage is the high construction costs of the construction of dams, occupying large areas of often agricultural, negatively affecting the hydrological and ecological properties of watercourses, thermal and hydrological changes in mesocling, relatively rapid flooding of the reservoir with sediments, interruption of ecological continuum of the landscape. [76]

The following types of hydroelectric power plants are distinguished [76]:

- **large hydroelectric power** plants (Fig. 52) - they are usually connected to dams holding huge amounts of water (Asuan Dam on the Danube in Egypt, dams in Siberia on the Ob and Yenisei River or our Gabčíkovo dam on the Danube, etc.),
- **pumped hydroelectric power plants - they are built as power plants providing energy supply in the so-called energy peak (impact-higher energy consumption** in the morning or evening). They are usually built in mountainous areas by building a water tank at a higher altitude, into which water is pumped from the reservoir at a lower altitude at times of lower energy consumption. Both tanks are connected by a pipe through which water flows to turbines at peak times. Building such power plants is economically very costly.
- **small** hydroelectric power plants (Fig. 53) - they are built on small watercourses. They supply electricity to the nearest neighborhood. These power plants do not constitute a large source of energy, but a number of them can be built. These are power plants with installed capacity up to 10 MW.

Fig. 52 Hoover Dam U.S. Hydroelectric Power Plant [77]

Fig. 53 Small hydroelectric power plant [78]

They can be divided according to various criteria, the most important of which are installed power (mobile sources - up to 2 kW, micro-sources - up to 35 kW, small power plants - up to 60 kW, industrial - up to 10 MW), gradient (low pressure - with a gradient up to 20 m, medium pressure - with a gradient up to 100 m and high pressure - with a gradient above 100 m) and The main reason why hydroelectric power plants do not become available wherever possible is that they are relatively expensive and have negative ecological and social impacts associated with them. It applies mainly to large hydroelectric power plants. [76]

Wa wa wa wading is part of an ecological system in which one change may trigger subsequent changes in other parts of the system. An example is the change in the flow of water in the river, which can trigger changes in water quality and aquaticliving conditions, especially fish. Dams that are part of most large hydroelectric power plants can significantly affect the living conditions of fish. In addition, the newly created dam lake usually separates fish stocks living at the bottom and top of fat, blocking their migratory pathways.

The ecological impacts of such waterworks can still be monitored very far from the dam site. Watercourses and precipitation activities are interrelated. Watercourses can affect not only the local climate, but also the level of groundwater in their surroundings. Sedimentation in lakes can lead to increased erosion at the bottom of the flow. [76]

Nuclear (nuclear) power plants

Nuclear power plants (Fig. 54) use uranium and its chemical reactions for energy production. From the point of view of ecology, this is the purest electricity, but the main problem is the storage of nuclear waste and the large amount of water needed for cooling. Another risk for nuclear power plants is the risk of an accident, the consequences of which can be catastrophic. [95]

The essence of nuclear energy acquisition is the natural radioactivity of uranium. At the end of the 19-th century it was discovered by M. Curie – Skladowská and H. Becquerell on Jachymovské Smolinci (uranit - UO_3).

Fig. 54 Nuclear power plant [79]

The fission of the unstable nucleus nucleus of uranium-235 produces nuclides with a lower atomic number (a lower number of protons in the nucleus) and a mass that moves very quickly while releasing 2 - 3 neutrons, which can induce the fission of other nuclei of uranium atom 235. That's how the nuclear reaction can spread. With a sufficient amount of accumulated uranium (supercritical amount), the amount of energy that leads to the explosion (atomic bomb) and spraying of the radioactive elements produced in a wide area is released. [95]

In a nuclear reactor there is a fuel that contains only a few uranium - 235 - the so-called enriched uranium - 238 is actually uranium, which contains e.g. 3,6 % uranium - 235. In this case, an avalanche reaction, as in an atomic bomb, can not take place. In addition, the design of the nuclear reactor maintains the response process at the necessary level, the moderator captures part of the released neutrons. [95]

Fissile reactions take place in a nuclear reactor, releasing a significant amount of heat that is used to generate electricity in a similar way to heat derived from fossil fuel.

To obtain 1 kg of nuclear fuel, it is necessary to extract about 2 - 4 t uranium ore. From 1 kg of nuclear fuel, about as much energy is obtained as from 100 t quality hard coal.

The use of nuclear energy is at a very different level in the world. France receives around 70 % of its electricity from nuclear power plants, on the contrary, countries where the original ideas of expanding nuclear power plants are being reduced (Sweden, USA) or where this energy source is completely rejected (Austria, Norway). The world's largest nuclear power plant, Fukearsma, is located in Japan but was built in a very unsuitable place within range of the tsunami- which was the cause of a majornuclear disaster. It had 10 reactors and a power of about 8 GW. [95]

In view of the necessary safety measures, the construction of nuclear power plants is becoming so costly that this source of energy is prospectively no longer envisaged.
There are two nuclear power plants in our country: Mochovce (Fig. 55) and Jaslovské Bohunice (Fig. 56), using reactors other than Chernobyl. They generate 53 % of the energy consumed [95].

Fig. 55 Mochovce [79]

Fig. 56 Jaslovské Bohunice [80]

5.7 Renewable and Inexhaustible Energy Sources

Renewable and inexhaustible **energy sources are considered prospective energy** sources.

They are mostly based on the **Sun.** Signs of solar energy on Earth include [1]:

- **fossil fuel energy** generated in the distant past from plant or animal biomass (coal, oil, natural gas),
- **wind energy** - generated by airflow between unevenly heated parts of the planet,
- **biomass energy** - is generated by converting solar energy into the energy of chemical bonds in organic compounds using photosynthesis. This includes not only the use of biomass in combustion, but also the food use of animals,
- **hydropower** - where solar energy is the driving force for the water cycle,
- **heat** - is mostly a manifestation of losses in energy conversions,
- the immense power of **solar energy.**

The manifestations of solar energy on Earth do not include [11]:

- **geothermal energy and** its manifestations - this energy comes from the time of the formation of the Earth and the Solar System at all. It is formed by nuclear decay and the action of flap forces,
- **the energy of the gravitational** forces, in particular the kinetic energy of the Moon-Earth-Sun system, manifested as tides,
- **energy of atomic nudes** - arising from the radioactive decay of heavy-duty elements such as iron or vice versa when merging lighter elements,
- **the energy of space radiation** coming from sources outside the Solar System.

5.7.1 Solar Radiation

As one of the stars of our galaxy, the sun (Fig. 57) represents a highly stable and high-performance energy source without which life on Earth could not be avoided. The sun's energy originates from a fusion proton-neutron reaction. The reaction takes place at temperatures of up to 14 million ^{o}C while the surface temperature of the Sun reaches on average "*only*" 6 000 ^{o}C. This means that the Sun has enough nuclear fuel in the form of hydrogen to glow evenly for another five billion years until the nuclear response is gradually stopped and the star disappears. [11]

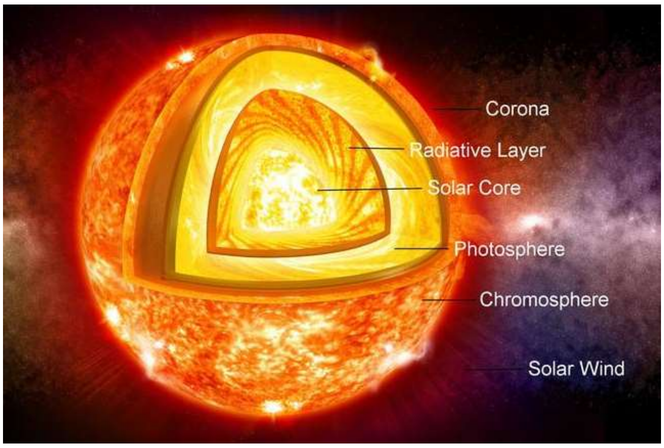


Fig. 57 Structure of the sun [81]

The amount of solar energy hitting Earth is nearly 14 000 times greater than all the energy consumed by mankind today. The energy continuously supplied by the Sun to Earth is 180 000 TW, while the total energy needs of mankind are only about 13 TW. About 1 360 watts of energy per square meter per square meter fall to the limit of earth's atmosphere at the perpendicular impact of the sun's rays. Fluctuations in the intensity of sunlight are mainly due to the elliptical orbit of the Earth around the Sun. This figure is usually referred to as the 'solar constant' (Fig. 58). From an energy point of view, this is therefore an extremely interesting possibility of obtaining energy. Its limited use is due to technological and economic problems, as well as to the prey behaviour of human civilisation, which draws on the lightest natural resources available, regardless of future generations [1].

Solar energy impacts on the Earth's surface in the form of sunlight. After impact on the Earth's surface, sunlight is converted into other forms of energy [1]:

- **for thermal energy** - in this way the earth's surface is heated - soil, water and air,
- **for mechanical energy** - this is how air currents are generated,
- **to chemical energy** - which through photosynthesis is bound in plants and other organisms.

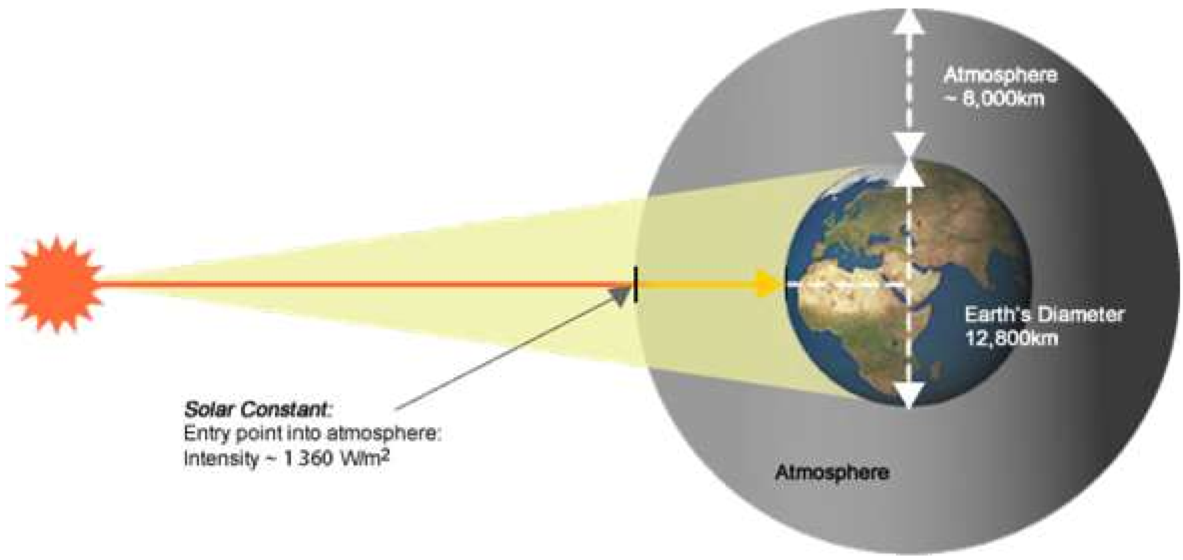


Fig. 58 Solar constant = 1 360 W/m^2 at the level of the limit of the Earth's atmosphere [82]

The intensity of sunlight decreases through the atmosphere, thanks precisely to the conversion of radiation into individual forms of energy and also to the dispersion on individual parts of the atmosphere (Fig. 59). Therefore, on the Earth's surface, we register three basic types of sunlight - **direct sunlight, diffuse (diffuse) radiation and radiation** reflected either from the earth's surface or other objects (Fig. 60). We perceive all these components to varying degrees with the free eye and are able to use them with the help of solar collectors [1].

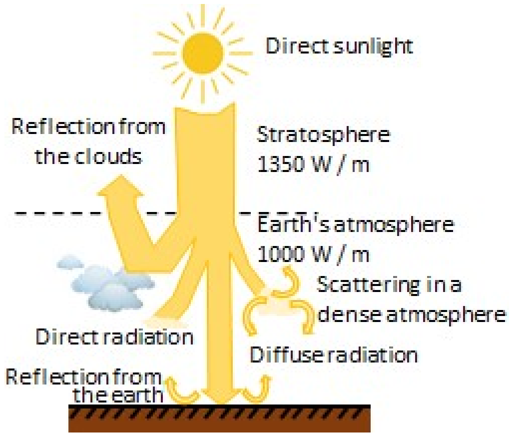


Fig. 59 Dispersion of sunlight in the atmosphere [83]

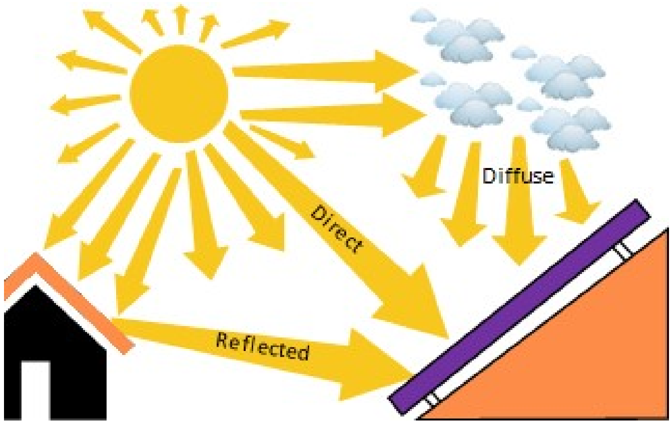


Fig. 60 Components of sunlight near the Earth's surface [83]

The intensity **of direct** sunlight at the limit of the Earth's atmosphere is approximately 1 360 W/m^2. From this, the atmosphere penetrates the Earth's surface under the most favorable conditions of approximately 1 000 W/m^2. Diffuse radiation is produced by dispersing direct radiation on clouds and debris in the atmosphere and **bouncing off the terrain.** The sum of direct and diffuse radiation is referred to as global **radiation** (Fig. 61) [1].

In our geographical conditions, this means that energy falling on a horizontal area of 1 m^2 contains a value of 1 000 to 1 250 kWh/year (approximately 5 GJ). It is the same amount of energy as approximately 150 m^3 of natural gas. The above-mentioned radiation intensity shows that theoretically at 100 % efficiency of the use of this energy, an area of 3 x 3,3 m could get enough energy to cover the year-round consumption of heat and hot water for the average household in Slovakia. The barrier to such use is not only the unfeasable 100 % efficiency of the device, but also the deviations in the amount of incident radiation during the year and its energy density. The density of sunlight is many times lower than that of burning fossil fuels, but on the other hand, this radiation is more homogeneously distributed than the reserves of conventional fuels on Earth [11].

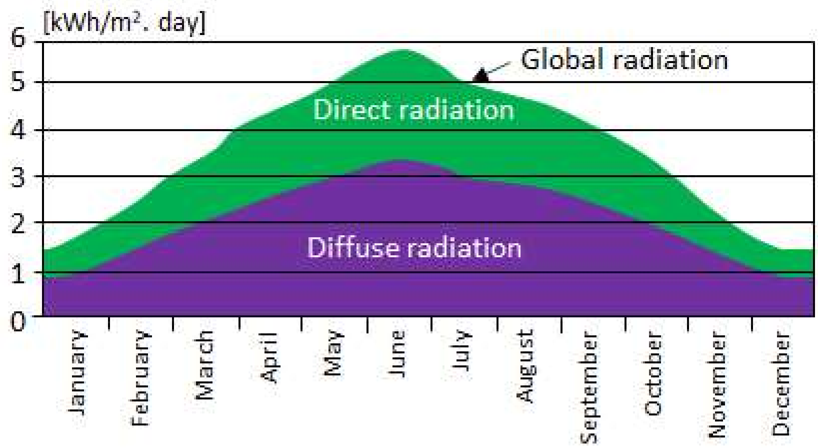


Fig. 61 Representation of individual types of radiation during the year in Slovakia [83]

The most sunlight is recorded throughout the year in the south of Slovakia, at least in Orava and Kysuce, while the difference between the coldest and warmest regions in the falling amount of energy is only about 15 %. A summary of the annual global horizontal radiation in Slovakia (kWh/m^2) is given in Fig. 62.

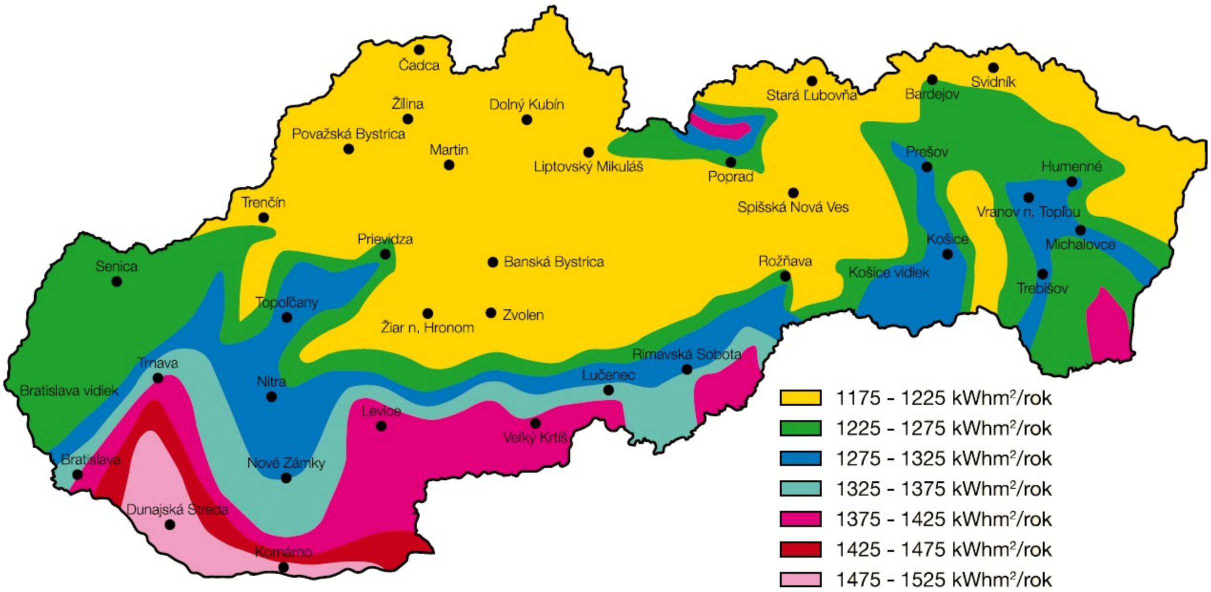


Fig. 62 Summary of annual global horizontal radiation in Slovakia kWh/m^2 [83]

Solar energy is also used in accumulated - **accumulated** - in different parts of the environment - in the air, in water, in the soil using the so-called "*solar energy*" **heat pumps.**

The heat pump (Fig. 63) is one of the alternative energy production facilities, but it is not an energy source (which is sometimes presented mingly). It is an economically advantageous and environmentally friendly source of heat acquisition. It works on the principle of thermal exchange between the heat source around it and the medium it heats up. This source may be surrounding soil, air, groundwater or surface water, or waste heat from industry or livestock farming [84].

A conventional heat pump can heat water to 55 °C, enough heat to be used to heat or heat hot service water.

The heat pump can produce up to three times more thermal energy than other heating sources at the same consumption when consuming 1 kW hof electricity. It can therefore save about 2/3 of its total energy [84].

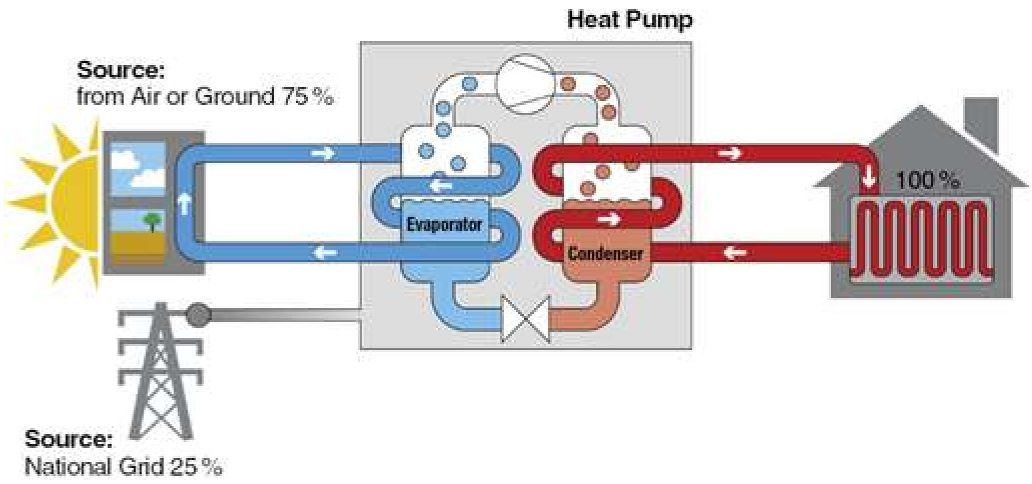


Fig. 63 Heat pump functional diagram [83]

An important function in the heat pumping system is the coolant, the so-called working medium, which evaporates even at lower temperatures. The system works by taking heat from the surroundings - from water, air or soil - in the heat exchanger. Subsequently, its state turns into gaseous, the compressor sucks it in, pressing increases its pressure and temperature. Electricity is needed to run the compressor, which is later used in the form of increased energy potential of the working medium. This is further transferred to the capacitor, where it hands over the heat to another substance. For example, water or air for hot water or hot air heating. With this replacement, the working medium passes into the liquid state and is again ready to receive heat from the surroundings. In this way, the whole system circulates.

Benefits [84]**:**

- high efficiency - ratio of heat received and passed,
- low immediate long-term electricity consumption,
- less dependence on rising energy prices,
- low servicing and maintenance requirements,
- long service life of the components used.

Disadvantages:

- Higher investment costs.

Depending on the surroundings and the type of medium receiving heat from it, three types of heat pumps are distinguished:

Air/water

The use of heat contained in air is the easiest, since this system can be implemented without technical limitation. The heat pump works up to air temperatures - 15 °C. It is unbelievable that even such a cold can be a source of heat. Of course, the efficiency of the pump is low in such temperatures. If the temperature of the outdoor air drops below a certain limit (mostly -5 °C), it is preferable to heat the backup heat source. On the contrary, excellent efficiency is achieved by the pump in spring and autumn, i.e. in transition periods when the air temperature is higher than the temperature of the ground or water. It is the large fluctuations in air temperature that are the main source of this energy. In addition to fresh air, household-generated air (e.g. controlled ventilation) can be used effectively in agriculture, where pigs and cattle are a major source of heat (Fig. 64) [84].

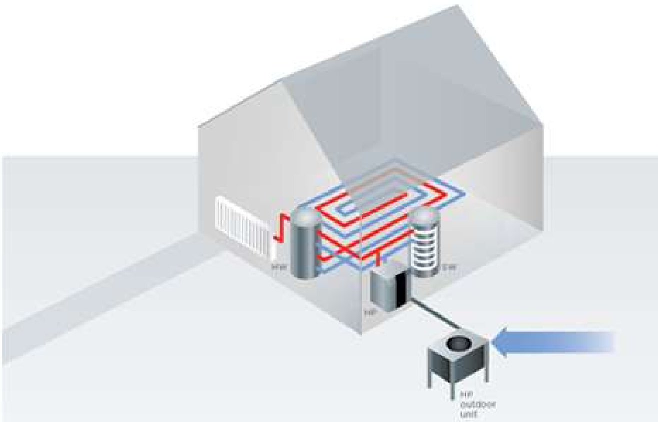


Fig. 64 Air-to-water heat pump [84]

Water/water

Groundwater is a very suitable heat source for the heat pump for its constant, relatively high temperature (about 10 °C). The prerequisites are favorable hydrogeological conditions (whether it can be used as a heat source) and sufficient groundwater yield (for a family house must reach 0,5 l/s). Two wells are needed for the pump, which draws heat from the water, to function - one of which the water is pumped by the propulsion pump and cooled to the other, returning. The distance between wells is from 10 to 25 m. In addition to groundwater, surface water from stream, river, lake and wastewater from industry or households can be used. The use of groundwater must be approved by the water management authority (Fig. 65) [83].

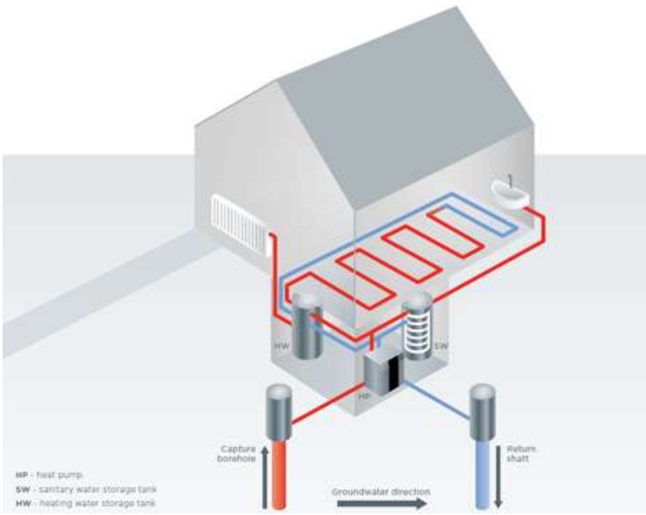


Fig. 65 Water-water heat pump [84]

Soil/water

In our climatic conditions, the earth does not erm at a depth of more than 80 cm. Therefore, this source can also be considered temperature-stable. Heat transfer between the ground and the heat pump mediates plastic pipes stored in the ground horizontally or in perpendicular boreholes. Horizontal storage is less costly (up to 50 percent compared to earth probes), but it requires two to three times the area of collectors, such as the area of heated space, to heat the family home. The pipe is deposited at a depth of 1,5 to 2 m, with a distance between pipes of 1 m. The length of one pipe shall not be more than 350 m. If this length is not enough, more pipes must be deposited, which must be the same length. In order to overheat as much as possible, the area of the ground below which the collector is located must be as little shaded as possible. If the plot or other conditions do not allow the use of horizontal collectors, deep boreholes are used, which can be done for each house, since they occupy at least a minimum of space (Fig. 66 and Fig. 67) [84].

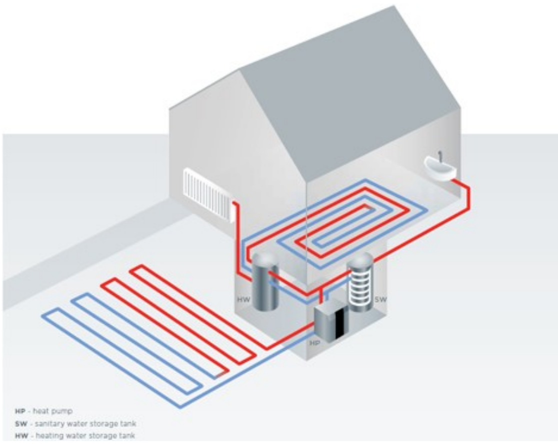


Fig. 66 Heat pump soil/water [84]

Fig. 67 Soil/water heat pump [84]

The advantage of deep boreholes, as with groundwater, is a relatively high temperature even on cold days, that is, when we need heat to heat households. Boreholes tend to be up to 120 m, so the problem is their high difficulty (1 m of borehole costs 40 € to 46 €). The exact depth of the borehole depends on the geological performance of the pump. If a greater depth is required than the geological conditions or technical possibilities allow, the total length may be divided into several identical wells at least 5 m between them [84].

If the individual wells are shorter than 50 m, it is recommended to increase the total length of the pipe (and therefore the wells) by 10 % [83].

Heat from the soil is transmitted by means of an antifrethese mixture, through which polyethylene tubes are filled. Circulating water takes heat from the ground, which is processed and handed over in the pump. Through this process, the earth is cooled, which is manifested, for example, by its later crushing. This factor should be taken into account when designing the heat pump and place the pipe so that the cold of the ground does not endanger the house or plant. The most suitable soil for heat pumps is moist clay soil, which conducts heat well [84].

5.7.2 Energy of the Seas and Oceans

Seas and oceans have long been considered a very promising source of energy. The movement of water in the oceans carries with it huge energy in the **form of tides,** the movement of sea waves and ocean **temperature gradients** [85]**.**

5.7.2.1. Wave Energy

Much of the energy coming to Earth from the Sun turns into wind, which in turn gives strength to sea waves. The energy drifting from sea waves is huge and reaches about 70 MW/km of wave front (Fig. 68). Such waves travel great distances without losing their strength. Storm-generated waves in the middle of the Atlantic normally travel to the coast of Europe without substantially losing their energy. All energy is concentrated close to the surface of the water and little energy is drifting at a depth of more than 50 m [85].

Fig. 68 Sea waves [86]

Wave energy changes from place to place, and in general it can be said that the greater the distance from the equator, the greater the energy of the sea waves. This energy is proving to have great potential globally. With an average efficiency of about 25 % and using only the most advantageous locations representing 4 % of the total potential that could be used in the next 50 years, sea wave energy could cover about 1 % of global electricity consumption, representing approximately 100 thousand MW of power [85].

The development of these power plants takes place mainly in coastal countries such as Japan, Great Britain, Ireland, Norway and Denmark. However, existing installations still have the character of prototypes. Currently, two main types of equipment located close to the coast or at a distance of several kilometers from the coast in deep waters are considered (Fig. 69). Installations close to the coast are based on the principle of an oscillaising column of water located in a large chamber (similar to an inverted glass) having wave holes and an air turbine mounted at the top of the appliance (Fig. 70). When waves enter the device, the air in it is compressed, this pressure being transferred to the air turbine generating electricity. Pilot power plants of this type have been built in Japan, India, England and Norway [85].

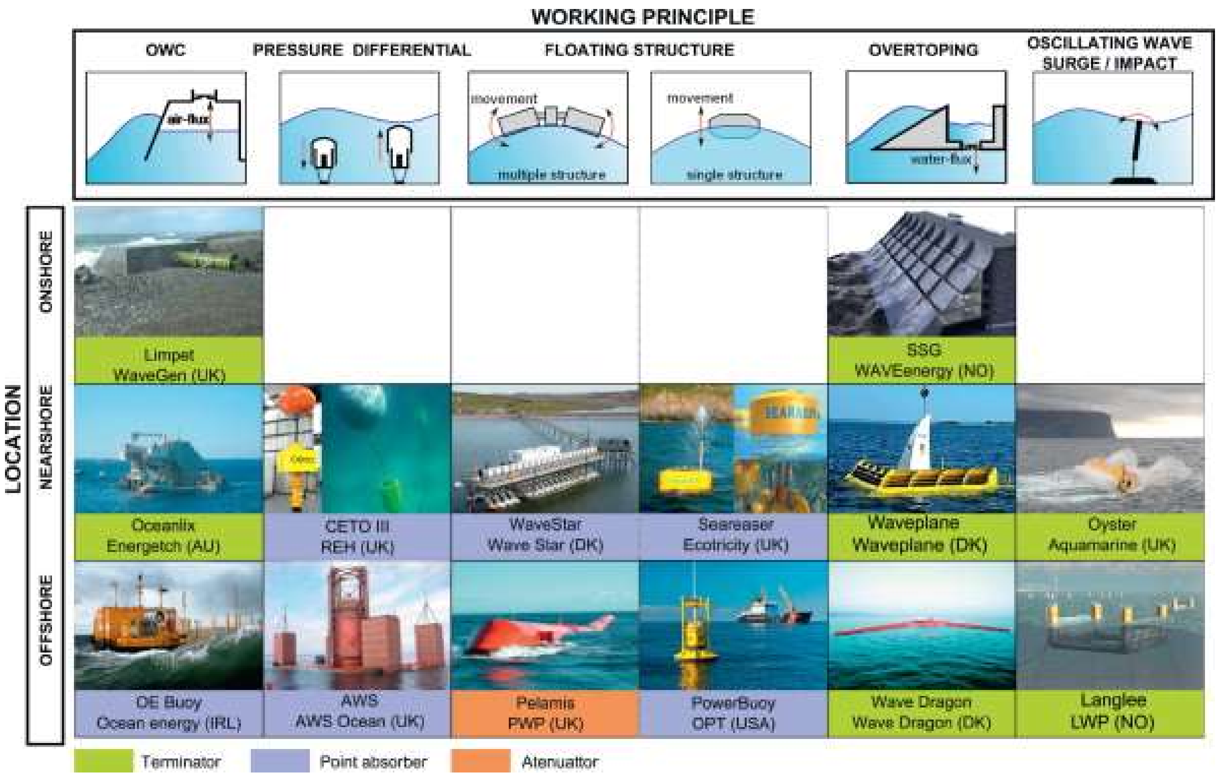


Fig. 69 Offshore wave energy test sites [87]

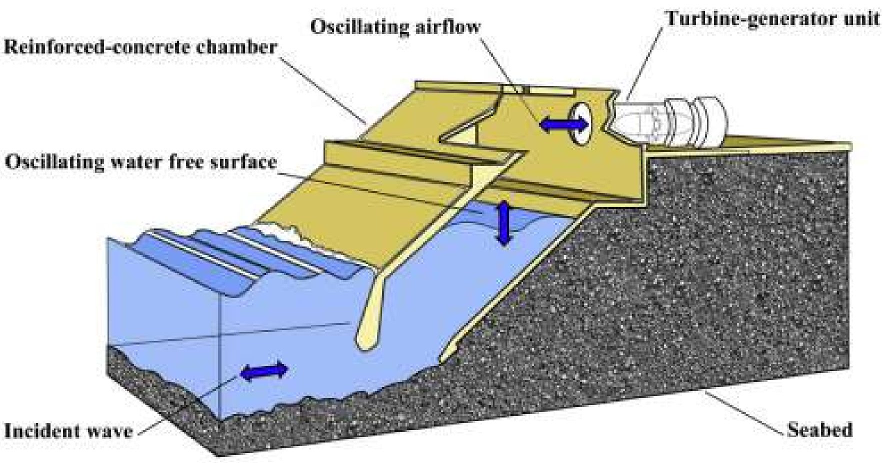


Fig. 70 Schematic cutaway of an OWC device with a Wells turbine [88]

5.7.2.2. Sea Tides Energy

Tidal energy differs from other energy sources in that it originates from potential and kinetic energy based on the moon's action on Earth. The tide is a consequence of this action and manifests itself on all ocean and sea coasts. Water levels change regularly twice a day (rising and into forests) leading to efforts to harness this energy. All these efforts are based on filling and emptying the natural reservoir with water. Tidal and tidal water can thus pass through a turbine located in a dam and generate electricity. It is true that the higher the tide, the more electricity can be produced [85].

The global potential hidden in tidal energy is estimated at around 3000 GW (3000 larger nuclear power plants). Some experts estimate that of this potential, about 2 % could be technically exploited - 50 times less than the power of all hydropower plants. At present, it is economically possible to use the tide in places where it reaches a height of at least 5 meters. Such an influx occurs in many places of the world, especially in areas where there are bays that can intensify the tide. The bays can be easily reassed and replenished with a water turbine [85].

The technology using tidal energy is very similar to hydroelectric power plants using low water catchment. The main difference between tidal power plants and conventional hydroelectric power plants is that, in addition to salt water, turbines have to operate at variable gradient heights. In addition, electricity is produced in them for only a few hours during the day. Ultimately, this means a reduction in overall efficiency. Tidal power plants thus generate only about a third of electricity as power-comparable hydropower plants [85].

Interest in building tidal power plants has persisted since the late 1960s. At first, there was an effort to build such dam tidal power plants in the estuary of narrow and long bays. From an engineering point of view, this solution proved feasible but had several negative impacts from an ecological point of view. There are currently 3 commercial tidal power plants working on this principle. The largest of them with a power of 240 MW was put into operation in 1967 at the mouth of the River La Rance near St. Malo in France. Another 1 MW power plant is located in the Russian part of the White Sea and has been operating since 1969. The third 16 MW power plant is located in Nova Scotia, Canada. The ecological problems associated with the dams of watercourses and bays have prevented the construction of other dam-type power plants. The main problems with the gulf oversteer are that such a barrier restricts fish migration, ship traffic and, moreover, increased sedimentation in the bay. This also affects other living organisms in the area. Reduced water levels negatively affect the life (nesting) of birds, which is also manifested in more distant areas [85].

The Tidal Power Plant in La Rance (Fig. 71) works by releasing water into the reservoir in the tidal shed and releasing this water back into the Atlantic Ocean in the tide. The water passes through 24 turbines connected to generators generating enough electricity for about 300 000 inhabitants. The power plant has turbines that can operate as pumps and use the entire system as a pumping hydroelectric power plant to relieve the load on the electricity grid. At a time of low load, water is pumped from the ocean to the reservoir behind the dam, thus increasing the level usable in electricity generation. The height of the tide is thus up to 13,4 meters, while the dam is 760 meters wide. In 1997, turbines were installed in this tidal power plant, which use both tidal and tidal water to generate electricity [85].

Fig. 71 Tidal hydroelectric power plant in the estuary of the French River La Rance [89]

5.7.2.3. Coastal Currents

Although the technology using tidal energy by the gulf oversteer has been proven in practice since the early 1990s, the interest of engineers has focused mainly on the use of offshore currents for electricity generation. Such currents arise in coastal waters as a result of forces acting on the seabed, which push currents in narrow channels in a similar way to the very strong winds in the valleys or hills. Because the density of water is up to 832 times higher than the density of air, currents with speeds of e.g. 16 km/h carry energy as winds of up to 390 km/h. Unlike strong winds, tidal currents can be predicted as the tide causing currents alternates every 12 hours [85].

Coastal tidal currents can be used so-called "*tidal currents*" **tidal turbines** (Fig. 72). However, these turbines, which are similar to wind turbines located underwater, are still underdeveloped. Prototypes work reliably and economically in places where currents reach speeds of 2 - 3 m/s. The disadvantage is that at higher speeds they are more stressed and at lower speeds their operation is uneconomic. A tidal turbine with a rotor diameter of 20 m can produce as much energy as a 60 m diameter wind turbine. The advantage of tidal turbines is that they cannot be seen or heard, and the entire device except the transformer is located below the surface of the water [85].

There are several suitable locations in the world for the location of tidal turbines, and some experts estimate the potential of this resource at more than 330 thousand MW. Such places are located mainly off the coasts in Southeast Asia. The ideal place for the location of the tidal turbine is at a depth of about 30 m, while these turbines are able to generate 10 MW of electricity from each square kilometer. In the EU, 106 sites suitable for these turbines have been identified - 42 of which are located in waters around the UK [85]. The first tidal turbine is to be located off the south-west coast of England. It shall have a rotor diameter of 12 - 15 m and an installed capacity of 300 kW, which is sufficient to supply the small village with electricity. The expected price of electricity produced is 0,10 $.

Fig. 72 Tidal turbine [90]

5.7.2.4. Energy of Ocean Temperature Gradients

The surface layers of the oceans and seas are seizing and absorbing sunlight. They can therefore be regarded as collectors and accumulators of solar energy at the same time. The temperature difference between the warm surface and the cool depth layers of the oceans can be used to drive thermal motors (pumps). The difference in temperatures of surface layers and deep layers depends on the geographical location and time of year, and in fact this difference is small, around 15 to 22 °C [85].

The efficiency of thermal engines operating at these low temperature gradients is also low. Because the ocean surfaces are vast, they represent a viable energy source.
In France, they developed a power plant with a capacity of 3,5 MW, where cold water is pumped from a depth of 5 km, thus reaching a temperature difference of 200 °C for the hunt for thermal engines [85].

However, the cost of obtaining energy from the seas and oceans is still too high and does not seem a cheap prospect for decades to come when summarising environmental risks.

5.7.3 Geothermal Energy

Geothermal energy is not, in the truest sense of the word, a renewable source of energy, since it originates from the hot core of the Earth (Fig. 73), from which heat escapes through volcanic fissures in rocks. However, given the huge almost inexhaustible reserves of this energy, these sources areamong the ranked. The core temperature (Fig. 74) is estimated at more than 4 000 °C and there is enough energy in the 10 km layer of earth packaging available to the current drilling technique to cover our consumptionover a period of several thousand years. The heat progresses from the glowing earth's core towards the surface [92].

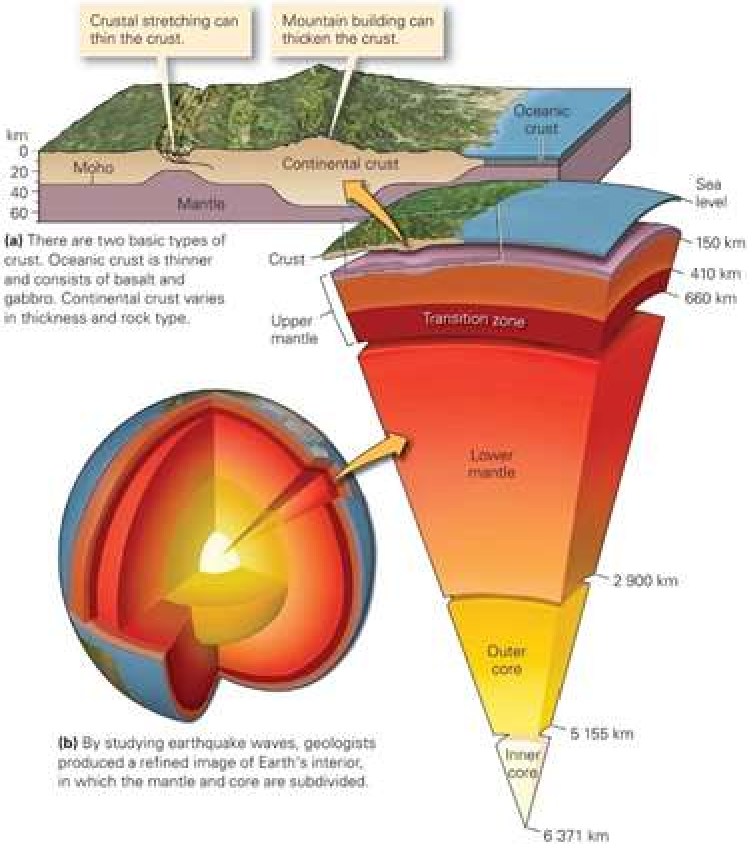


Fig. 73 Earth Structure [91]

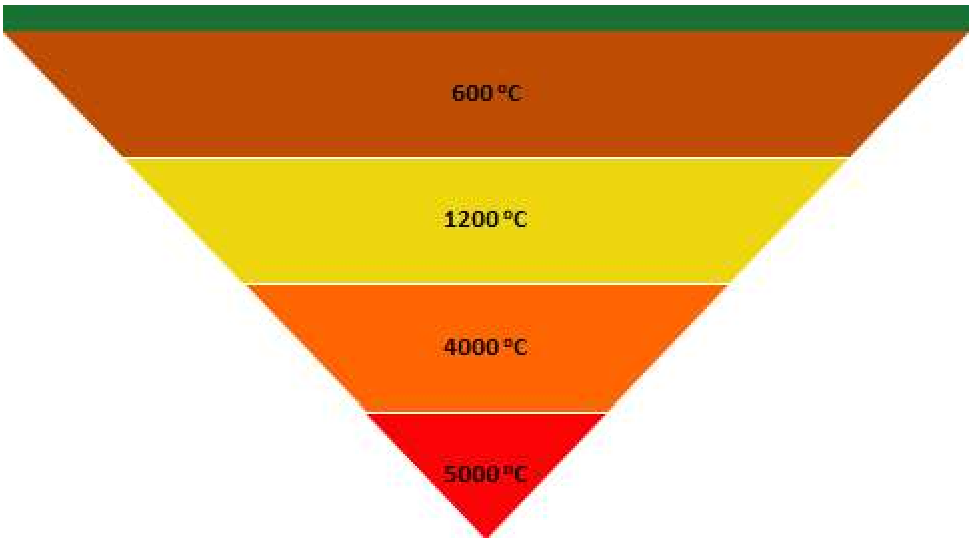


Fig. 74 Earth Temperature

The Earth continuously releases its heat in every place, while the temperature of the earth's cover increases with increasing depth. The temperature gradient for every hundred meters below the earth's surface is 2 to 4 °C. [92]

The use of geothermal resources goes far back. There are archaeological records that American Indians have already been ingesting territories near geothermal sources more than 10 000 years ago. Geothermal sources such as hot springs were also sought after by ancient

Romans, Turks or Maori in New Zealand. The first records of the industrial use of this energy date back to 1810, when the extraction of minerals found in hot geothermal waters in Larderello, Italy, began. Nine factories using geothermal water were built in the area between 1816 and 1835. [92]

Geothermal energy is mainly used for heating **objects** such as swimming pools, greenhouses as well as residential buildings connected to the district heating system. Such heating was installed as early as 1890 in Boise, Idaho. In Reykjavik, Iceland, 45 000 homes and 95 000 m of greenhouses were heated by geothermal water as early as 1960. The task force is made up of the so-called "*green card*" **heat pumps** using ground heat to prepare heat for heating. The distribution of the use of geothermal energy for heat production in the world is currently shown in Tab. 12.

Tab. 12
Use of geothermal energy [1]

	Capacity [%]	Energy [%]
Geoptermal heat pumps	42,2	14,3
Heating of objects	30,6	36,8
Pools	11,1	22,2
Greenhouses	8,5	11,8
Aqua cultures	3,2	6,6
Industry	3,0	6,5
Snow melting/air conditioning	0,7	0,6
Agricultural drying	0,4	0,6
Other	0,3	0,6
Together	100	100

Geothermal energy is also used to generate **electricity** (Fig. 75). The first attempts to generate electricity started in Italy as early as 1904 and the first 250 kW power plant was put into operation in Larderello in 1913. This was followed by others in Wairaki, New Zealand (1958), Tathe Mexico (1959) and The Geysers in the USA (1960) (Fig. 76). Since 1980, installed electrical power in geothermal power plants has increased significantly and in 2 000 it reached 7 974 MW, of which 2228 MW is installed in the USA. [92]

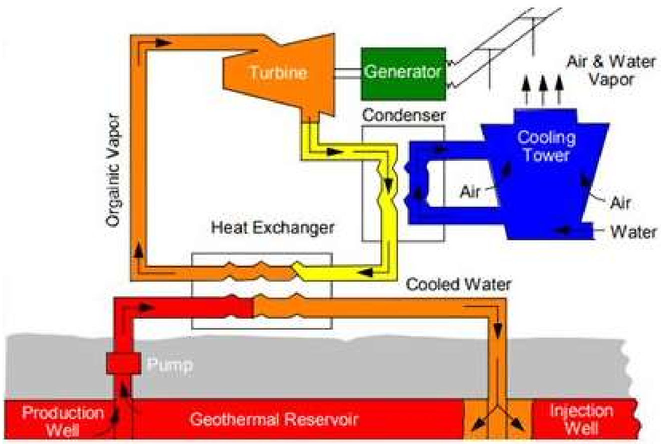


Fig. 75 Geothermal Power Plant Scheme [93]

Fig. 76 Geothermal Power Plant in Geysers, USA [94]

The territory of Slovakia is relatively rich in geothermal resources compared to other countries and 25 prospective areas were already allocated in 1993 (Fig. 77). The total potential of usable resources with low temperature waters (around 30 °C) is estimated at 5200 MW of thermal power. The potential of geothermal waters with a water temperature of 75 - 95 °C usable e.g. for heating buildings is about 200 MW.

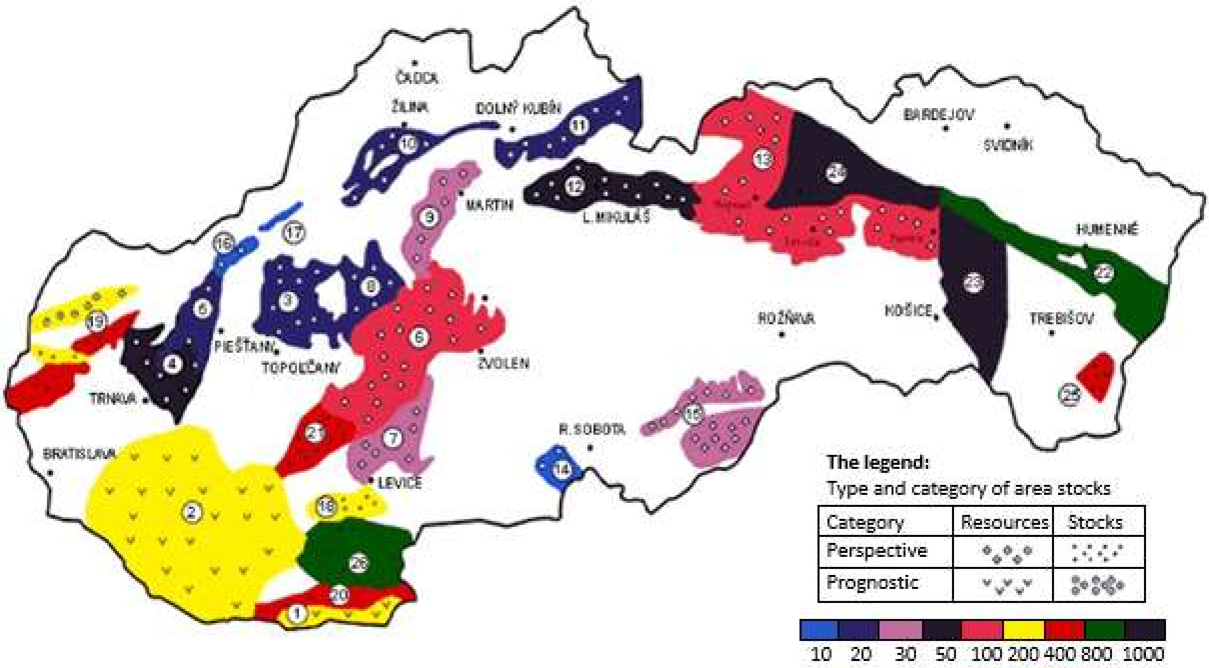


Fig. 77 Distribution of prospective areas of geothermal waters in Slovakia [83]

In the past, thermal springs were used in Slovakia mainly in agriculture. The technology used was very simple, the heat pumps and cascading use of the source were applied only exceptionally and the water energy was used quite wastefully. Many of these sources have been shut down in recent years as the mineral content of geothermal (waste) water, which stood at 4 g/l, has led to substantial surface water loads. The new limit – 0,8 g/l means that the use of geothermal energy is possible when the wastewater problem is solved, whether by re-injection or cleaning it [95].

However, energy prices from this source vary considerably depending on local conditions. In some regions, however, the cost of the energy thus obtained is comparable to that of fossil fuel energy. The price of geothermal electricity produced ranges from USD 0,02/kWh for older installations (The Geysers) to USD 0,06/kWh for newer installations. The price of thermal energy from geothermal sources varies in an even wider range, as this depends not only on the characteristics of the source, but also on the presence of potential customers in the vicinity [95].

The global installed capacity of geothermal power plants reached 15 854 electric megawatts (MWe) at the end of last year - Fig. 78).

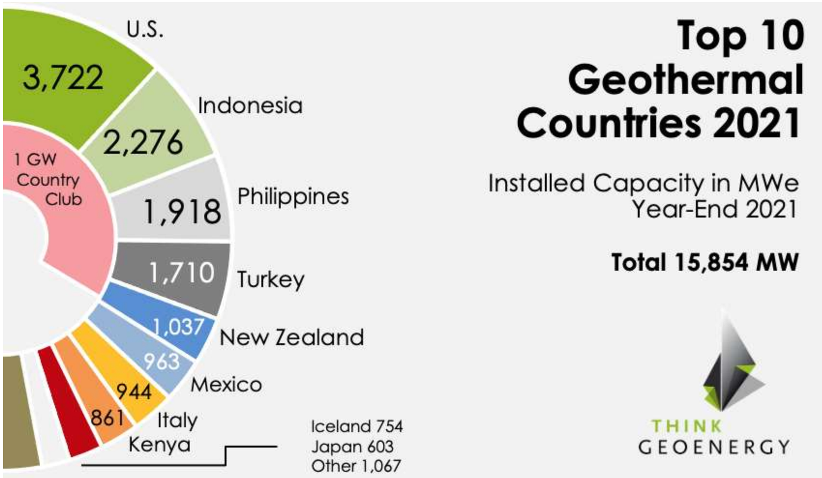


Fig. 78 Worldwide installed capacity of geothermal power plants [95]

The year-on-year increase was around 246 MWe. This means an increase in production of around 1 800 gigawatt hours per year, which corresponds to the consumption of almost half a million households (the EU average used for the calculation) [95].

The United States of America (3 722 MWe) has long led the country in terms of producing green electricity from geothermal sources. Most of the production there falls under the world's largest geothermal complex – The Geysers – in the state of California [95].

Second in the ranking, Indonesia recorded the highest increase in 2021, from 143 MWe in total at geothermal power plants in the country to 2 276 MWe. The increase was ensured by the launch of two large completed projects.

The island of the Philippines has also long focused on the use of geothermal energy to generate electricity. Although they do not record an increase last year, with a power of 1 918 MWe, they hold on to third place [95].

Above one gigawatt of installed capacity are still Turkey (1 710 MWe) and New Zealand (1 037 MWe). Both countries slightly increased their balance sheet in 2021 by increasing performance in expanding projects.

Turkey also holds the position of European leader, especially in the last decade, the use of geothermal energy has developed rapidly here. The state, with project support and financial instruments for investors, is also to blame for this [95].

Mexico (962,7 MWe) and Italy (944 MWe) follow in the ranking of top countries.

The eighth in the ranking is African Kenya, where geothermal energy generates a fraction of the total electricity. The installed capacity of 861 MWe is especially concentrated here in the extensive Olkaria complex (Fig. 79). In the final stage, there is a current expansion with another unit, which should come into operation soon [95].

Fig. 79 The Olkaria complex in Kenya is one of the largest geothermal projects in the world. From significantly helps speed up electrification [46]

Tiny Iceland holds on to the ninth place, the installed capacity here reaches 754 MWe. Only a smaller operation with a 300-kilowatt capacity was added, but at the same time a major expansion of the existing Reykjanes power plant (Fig. 80) in the southwestern tip of the island began. Iceland is known for producing most of its electricity from renewable sources, geothermal energy playing a key role in this [46].

Fig. 80 Reykjanes, one of Iceland's geothermal power plants with an installed capacity of 100 MW, is waiting for a power increase [96]

The ten countries with the highest performance are closed by Japan (603 MWe), which also did not report an increase, but even in its case, the development of several smaller projects continues [96].

The remaining 1 067 MWe of global installed capacity is taken care of by other countries. Among them, a new project has been put into operation in Chile, for example. The very first geothermal power plant was also completed last year in Colombia and Taiwan. A pilot project has also been launched in Bolivia [96].

According to the ThinkGeoenergy.com, in the current year 2022, more power plants are expected to become operational and the installed capacity to grow more dynamically. At the same time, an even larger volume of exploration and drilling work is designed.

In Europe, geothermal power plants are located in ten countries. Slovakia should also be included in the near future – already this year, projects near Žiar nad Hronom and Prešov should be moved into the implementation phase [96].

Domestic investor PW Energy is planning in the first stage in a locality in central Slovakia with the construction of power plants with an installed capacity of 12 MWe in two geothermal centers, in Šariš it is to be one resort with a 6-megawatt capacity in the initial phase. In both cases, electricity generation will be for tens of thousands of households, while the use of residual heat is envisaged [96].

Technology using geothermal energy is subject to permanent development, especially in the development of systems extracting hot water from a depth of more than 4000 m. The disadvantage that prevents the wider use of geothermal energy is that water contains large quantities of salts and therefore cannot be directly guided by water pipes and used as a source of drinking water. It can also not be used in a district heating system. Saltwould break down both water pipes and heaters. The use of geothermal energy to heat water is therefore not possible without the use of exchangers. New technologies use stainless exchangers and low-temperature heating systems. Modern applications include, but are not limited to, the use of geothermal energy for chemical production and clean water production. Measures to reduce undesirable ecological burdens from the use of this resource, e.g. water re-injection and soluble waste, are now becoming common practice. The emission of gaseous pollutants, in particular ulfan, is also effectively avoided. The costs of these measures are included in the economic analyses of geothermal projects [1].

In 1998, geothermal energy was used in 35 locations in Slovakia. The total yield of these sources is 110 l of hot water per second, while the heat output of the used sources is roughly 93 MW. In addition to the larger number of geothermal heated swimming pools, which require relatively low investment costs, the first facility using geothermal energy for heating housing estates and hospitals was built here. In cooperation with the Icelandic company Virkon-Orkint, the Geothermal Centre in Galanta was put into operation in 1996. The used power of the local geothermal source is 10 MW. The heating system in Podhájská has a total output of 8 MW.

Based on past experience (Galanta), it can be said that in several Slovak municipalities it would be possible to cover a significant part of the consumption of thermal energy in the residential and municipal sphere from such sources. Despite the fact that there are sufficient geothermal resources in our country, the problem affecting their wider use today lies mainly in the high financial costs. These are mainly related to geological exploration and drilling to a depth of often 1500 – 3000 meters. In terms of its potential, Košice basin, which is characterized by the presence of geothermal groundwater with a temperature of 120 - 160 °C at a depth of less than 3,000 meters, is shown as the most promising location in our country. For example, under the housing estate of Dargovské heroes, there is already water warm 60 °C at a depth of 800 m [1].

The project for the production of electricity from geothermal energy was proposed in Košice as early as 1990. He envisaged the construction of a 5 MW geothermal power plant, while waste heat from the power plant would be used to heat nearby buildings. Foreign technology was to be used at a cost of SKK 60 – 150 million (2 – 5 million €). The cost of two wells to a depth of 2500 meters would be SKK 80 million (€ 2,66 million). The construction period was 14 months. This project located in the area with the highest potential of geothermal energy in the Slovak Republic (Tab. 13) has not yet been implemented. Based on exploratory wells in the village of Ďurkov (12 km from Košice), it is also considered to build a geothermal facility that would provide hot water for heating Košice. Thermal source has a yield of 60 l/s and water would be pumped from a depth of 2 000 m [1].

Tab. 13

Potential of individual areas of Slovakia [1]

Site	MW's energy potential	Expected energy output MW	Annual energy production TJ
Košice Basin	1200	200	6000
Poprad Basin	70	25	220
Liptov Basin	30	10	100
Danube Basin	200	50	400
Lion cover	126	50	440
TOGETHER	1626	335	7160

5.7.4 Wind Power

Wind energy is a form of solar energy that arises from uneven heating of the earth's surface. The sun emits an energy equal to 100 000 000 000 000 000 kWh towards Earth. Of this value, approximately 1 to 2 % is changed to wind energy. It's 50 to 100 times more than the energy that all plants on Earth are going through to live biomass.

The wind, since it is present everywhere, has been used by man since time immemorial. Moreover, this energy is still attractive today, because its use does not produce any waste, does not pollute the air and does not have a negative impact on human health. Wind as the primary source of energy is free and can be used decentralized in almost every part of the world [97].

The use of wind power goes back several thousand years and is associated with the beginnings of human civilization, when man decided to use this energy to drive vessels. The simple sailboats that have been preserved to this day are more than 5 000 years old and come from Egypt. The oldest wind-driven mills come from today's Afghanistan and are more than 2 700 years old. Those devices were commonly used to grind grain in other parts of the world. In addition, they were also used for irrigation of fields on several Mediterranean islands. In Crete they are used in this way to this day. The first wind-powered water pump appeared in the U.S. in 1854. It was a simple wind rose with several small sails and a wooden tail that filmed the whole device in the direction of the wind flow. In 1940, more than 6 million such wind pumps worked in the US. In addition to pumping water, they were also used to produce electricity. It is reported that the struggle to populate the Wild West was also mastered thanks to wind pumps that fed water to huge herds of cattle. However, the 20-th century marked the emergence of new energy sources – electricity, oil and natural gas, which were pushed into the background by wind pumps. This situation lasted until the oil crisis of the 1970s, when interest in wind energy was revived. State support for development and research has given rise to the development of new technologies in many countries. The effort focused mainly on the production of electricity by wind turbines, which was related to the fact that in developed countries the pumping of water by wind aggregates is not as important as, for example, in developing countries [97].

At the beginning of the current development of wind power in the world, the development and production of small wind turbines stood. These small devices were used for simple applications, but after their performance gradually increased, they lost importance as a source of electricity for individual houses. At present, virtually all larger turbines supply electricity to the grid. This is related to the fact that the power of one turbine is usually much greater than that of one or more households. Moreover, in places where wind speeds reach an annual average of more than 5 m/s, wind farms have started to be built since the 1980s, which by their production exceeded the consumption of entire municipalities. The first such farms were built in California. In the USA, these farms are owned by private companies (independent producers) and not by large electricity acompanies. Although the construction of these resources was not without problems, the development of wind power could not be stopped, and today there are about 16 000 larger turbines in California that generate more electricity than San Francisco consumes annually [97].

Wind aggregates (Fig. 81) are built all over the world. They are also an ideal technology for developing countries, where there is currently a high demand for new energy production capacities. The advantage of wind farms is that compared to conventional power plants, they can be easily, inexpensively and in a relatively very short time to build and connect to the public network. Today, developed countries are showing interest in wind turbines not only in terms of environmental protection, but also for economic reasons. The price of electricity produced is still falling and in some countries it is comparable to the price of electricity produced in conventional power plants. Today, even the most conservative energetics predict a large development of wind technologies in the near future [97].


a)


b)


c)


d)


e)

Fig. 81 Wind aggregates [98]

Despite the positive developments, several experts believe that the increase in installed wind power could be even greater. According to the "*Wind Force 10*" study, wind power could account for about 10 % of global electricity generation in 2020 and installed power could reach up to 1,2 million MW. This would create about 1,7 million new jobs. This performance would mean more electricity production than its current consumption in Europe.

The global wind potential is estimated at 53 trillion kWh, about 17 times the target set in the Win Force 10 study. According to this study, the price of electricity produced should fall to USD 0,025/kWh by 2025. By implementing such a 10 % target, carbon dioxide emissions could be reduced by 1,8 billion tons in 2025 [98].

The best weather conditions for the construction of wind turbines are near the sea coasts and on the hills. However, the wind is also reaching sufficient intensity usable by wind aggregates in other places. The disadvantage is that the wind is less predictable than, for example, solar energy, but its availability during the day is usually longer than in the case of sunlight. Wind intensity up to a height of about 100 meters is mainly influenced by terrain and obstacles. Wind power is therefore more locally specific than solar energy. In hilly terrain, it can be expected that, for example, two places have the same intensity of incident sunlight, but the wind intensity may vary greatly due to the direction of the prevailing winds. For this reason, much more attention should be paid to the placement of wind turbines than solar collectors or cells. Wind power also shows seasonal changes in intensity and is the largest in the winter months and lowest in summer. This is exactly the opposite of solar energy, which is why solar and wind technology complement each other appropriately. Examples include conditions in Denmark, where the intensity of sunlight reaches 100 % in summer and only 18 % in January. Wind farms here produce 100 % of energy in January and about 55 % in July.

To calculate the energy produced by the wind aggregate, it is necessary to know several relationships. The energy is directly proportional to the area of the rotor, the third power of wind speed and air density [98].

Indeed, the development of wind farms in the world is turbulent and today represents the fastest growing electricity generation sector. Compared to 2000, when the total world's installed wind power capacity was 17 333 MW, there was already a huge increase in 2008, with a more than six-fold increase in capacity in 2000. This trend of expansionary growth has been maintained until today, when at the end of 2014 the total installed capacity of wind power plants was as high as 369 608 MW (369 608 GW). In the last 10 years, there has thus been a fivefold increase in wind capacity. This increase is conditioned by these factors – the initial increase in the price of oil in the 70s and the consequent reversal of thinking towards renewable energy sources. The significant development of wind energy is manifested in all regions of the world, but in particular Asia, North America and Europe are advancing [98].

The significant development of wind energy is manifested in all regions of the world, but in particular Asia, North America and Europe are advancing [98].

At the end of 2014, the world's most wind energy processing capacity was installed in Asia, with a total value of 142 777 MW (142 777 GW). The most significant producer of electricity generated by wind power plants operating in Asia is clearly the People's Republic of China, which accounts for a majority share of up to 115,433 MW (115 433 GW) in the total value of wind energy produced in Asia. The second largest Asian producer of wind energy is India, followed by Japan [98].

Europe ranks second in the total world production of electricity generated by wind power plants, and Germany is the leader in wind power. Within the European Union, wind farms with a total installed capacity of 142 GW are currently in operation, of which 131 GW are produced by onshore wind farms and 11 GW by offshore wind farms. In 2015, there was an 11 GW increase in installed capacity, overtaking hydropower, making it the third most widely used energy source in the EU, accounting for almost 16 % of total energy production. In terms of electricity consumption, wind power accounts for 11,4 % of total electricity consumption in the EU. Investment of around 26 € trillion contributed to the development of wind energy in the EU in 2015, 40 % more than was invested in wind energy in 2014. The country with the largest installed capacity of wind farms in the EU is clearly Germany, which has wind farms with a total installed capacity of up to 45 GW [98].

In 2015, 47 % of the newly installed wind farms were located on German territory. Spain is second only to Germany, with an installed capacity of 23 GW. Countries with an established wind capacity exceeding 10 GW are two more in the EU – the UK with an established wind capacity of 14 GW and France with a total installed capacity of 10 GW. (EWEA, 2016). The UK dominates the European market for offshore wind farms. UK offshore wind farms account for up to 54 % of all offshore installations in the European Union (CWEA, 2015) [98].

In total, 16 EU Member States have a wind capacity of more than 1 GW, and in nine of these countries the installed capacity of wind farms is more than 5 GW. The capacity of wind power plants installed on the territory of the Czech Republic was only almost 0,3 GW (300 MW) at the end of 2015. Wind turbines in the Czech Republic are installed in 87 locations and further investments in wind energy are planned for the future. Even less developed wind energy than in the Czech Republic is wind energy in the Territory of the Slovak Republic. At the end of 2015, the total installed capacity of wind power plants in Slovakia was only 0,0031 GW (3,1 MW), which ranks Slovakia in the very last place in the use of wind energy as a renewable energy source among all Member States of the European Union [98].

The world's third major producer of wind energy is North America, with a total installed capacity of wind power plants of 76 629 GW (76 629 MW) at the end of 2014. The united states plays the most important role in wind power in this region, with a total capacity of 64 770 MW (64,77 GW) of installed wind capacity (as of the end of 2014). In second place in the North American region is Canada, with a total installed capacity of 9 698 MW (9,698 GW). The least wind energy has long been produced in the Middle East region, where Iran is the sole producer, with a total installed wind capacity of only 117 MW (0,117 GW). The low level of wind power in the Middle East may also be due to excessive concentration on oil extraction, as the world's largest deposits of this fossil fuel are located on the territory of this region [98].

In the near future, a further increase in the total global production of electricity generated by wind power plants can be expected. According to GWEC (Global Wind Energy Council) forecasts, Asia will continue to dominate the global wind energy market and Europe will continue to maintain its position with stable capacity of installed wind farms, where there will also be a slight increase. Wind energy markets in the regions of Latin America and Africa are developing significantly [98].

Modern wind turbines usually consist of the following components (Fig. 82): rotor blades, rotor, gears, generator, electronics and control equipment.

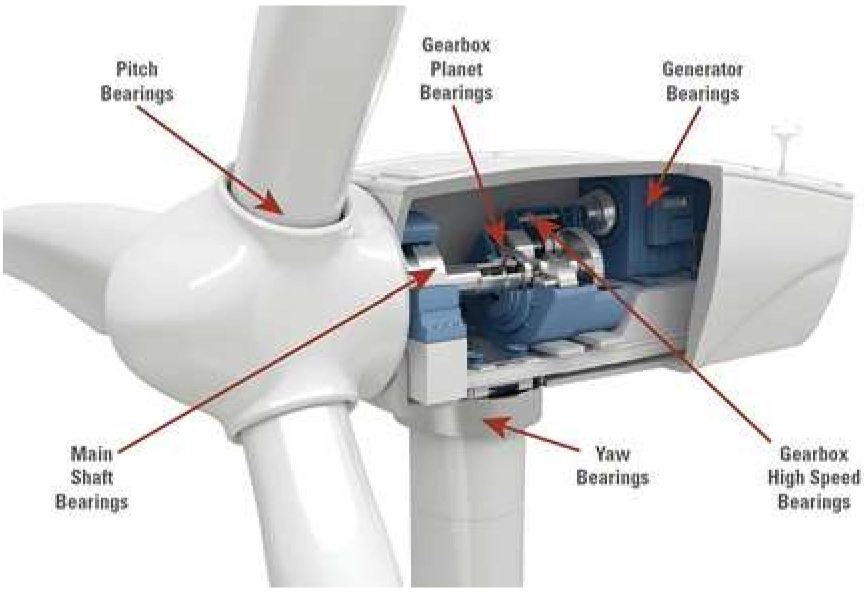


Fig. 82 Cross-section of the wind turbine [99]

In many places around the world, wind turbines are accepted as an environmentally friendly solution to the problem of electricity generation. As in other areas, production is not entirely without consequences for the surrounding environment. Here too, however, a distinction needs to be made between small and large turbines.

The prediction of wind turbine design and performance development is shown in Fig. 83.

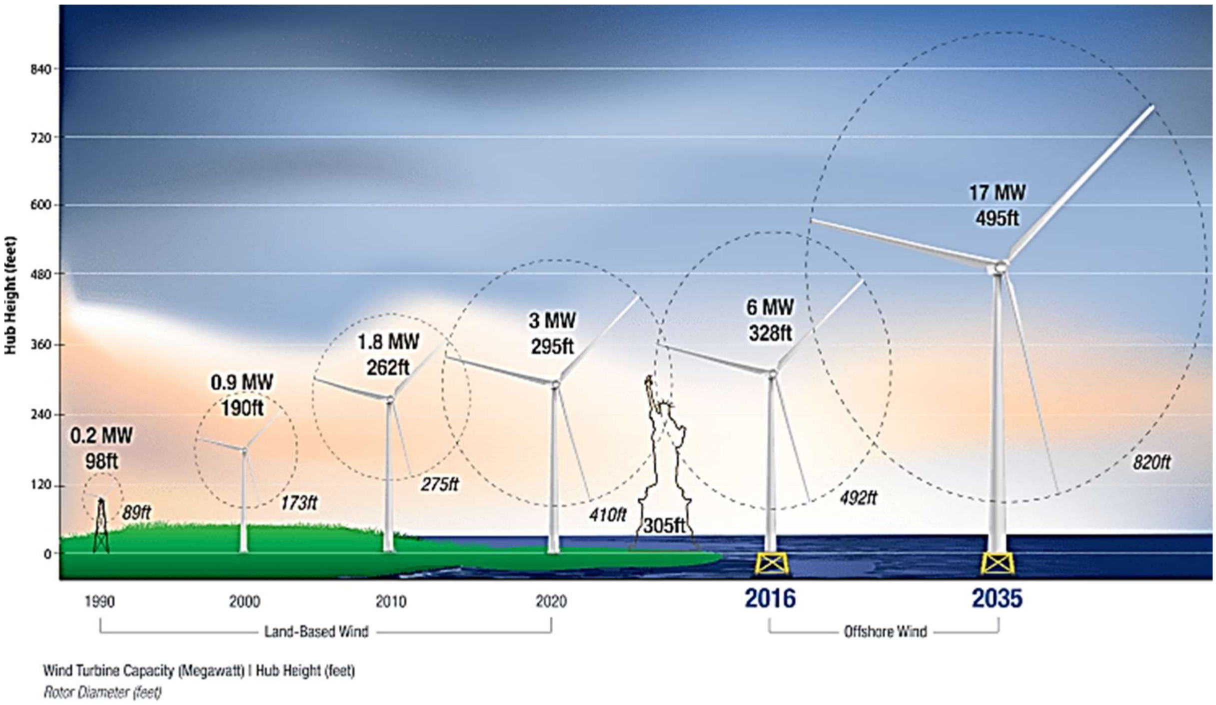


Fig. 83 Prediction of the development of wind turbine structures and performance [100]

Small turbines do not affect the surrounding environment in any way. In the case of larger turbines, noise, visual effect or interference of the electromagnetic field are reported as problem parameters.

The noise generated by wind turbines arises as a result of air turbulence as the top of the rotor leaf passes around the turbine mast and also as a result of the transmission running. Since this low-frequency noise is a sign of inefficiency and also in view of the complaints of the population, manufacturers are intensively addressing this problem. The result was a significant reduction in the noise of modern turbines. A critical noise level is considered to be 40 dBA (decibel), which is the level at which it is possible to sleep. This level is usually reached at a distance of less than 250 meters from a large wind turbine. However, the level of acceptable noise level is very individual. It is evident that the owner of the turbine sees noise as a sign of production and therefore of increased income, while uninvolved residents may have a different opinion. In several countries, there are legislative standards for placing larger turbines near human dwellings [100].

Wind turbines are visible from a long distance, and some population groups are seen as disruptive moments in the relief of the landscape. However, the truth is that the country is very often built by other tall objects, e.g. power poles, which are not criticised. In addition to negatively influencing the visual impression of the surrounding countryside, there is sometimes a risk-related problem for pilots of small aircraft flying low above ground. For them, high turbine masts can sometimes be dangerous.

Sometimes bird collisions with these devices are also reported as a problem associated with wind turbines. As studies from Denmark show, birds rarely hit wind turbines. In-line results showed that birds tended to avoid the turbine day and night at a distance of 100 - 200 m in front of it and fly past it at a safe distance. In Denmark, there are even turbines on masts, some bird species of which have formed nests (falcons) [100].

Television, radio and radar waves (electromagnetic radiation) are often disturbed by electric conductors. They may pose some risk to all metal parts of rotating turbines. At present, however, rotor leaves are made only from plastics and wood, which do not affect electromagnetic radiation. Even turbines located near airports do not have a demonstrable effect on radar stations.

5.7.5 Biomass

Biomass in the form of plants is chemically preserved solar energy. It is also one of the most versatile and widespread sources of energy on Earth. In addition to providing nutrition, it is used as a building material, it produces paper, medicines or chemicals, it is also an excellent fuel. Biomass has been used as a fuel source since the fire was discovered. Its advantage is that it offers not only a great diversity of input raw materials, but also universal use in the energy sector. It can be used not only **for heat production** but also **for electricity** production in modern combustion plants. Liquid and gaseous forms of biomass (ethanol, methanol, wood gas, biogas) can also be used to drive motor **vehicles.** Today, however, it is often considered to be low-quality fuel and does not even appear in energy statistics in many countries [101].

Biomass - basic data [101]**:**

- total biomass mass on Earth (including moisture) - 2 000 billion tonnes,
- weight of plants on land - 1 800 billion tonnes,
- mass of forests on Earth - 1 600 billion tonnes,
- mass biomass per inhabitant of the Earth - 400 tonnes,
- energy stored in biomass 25 000 EJ,
- net annual weight gain of biomass on land - 400 billion tonnes,
- annual increase in energy stored in biomass on land - 3 000 EJ/year (95 TW),
- total consumption of all forms of energy on Earth per year – 400 EJ/year (12 TW),
- biomass energy consumption - 55 EJ/year (1,7 TW).

Although the chemical composition of biomass varies from one plant species to another, on average plants contain about 25 % lignin and 75 % of hydrocarbons or sugars. The hydrocarbon component consists of many monosaccharide molecules linked to long polymer chains. Two important components of hydrocarbons are cellulose and hemicellulose. Nature uses long polymers of cellulose to build fibers that give plants the necessary strength. The lignin component acts as a binder that holds cellulose fibers together [101].

Plants use carbon dioxide from the atmosphere and water from the ground to grow, which they transform into hydrocarbons - biomass building blocks - thanks to photosynthesis. Solar energy, which is the driving force behind photosynthesis, is actually stored in the chemical bonds of this organic material. When biomass is burned, we regain the energy stored in chemical bonds. Oxygen from the air is associated with the carbon in the plant, creating carbon dioxide and water. This process is cyclically closed because emerging carbon dioxide is the input for new biomass (the CO_2 cycle in nature) [101].

Unlike wood, which has been used for cooking and heating since time immemorial, in the last few centuries mankind has mainly used a fossil form of biomass - coal. This fuel was created as a result of very slow chemical processes that changed the polymers of sugars into a chemical component that replaced lignin. This has made sufficient chemical bonds in coal a concentrated source of energy. All the fossil fuels that we consume today (coal, oil, natural gas) are basically ancient biomass. Over millions of years, natural processes have put the original biomass underground, gradually changing to these fuels. Although fossil fuels contain the same building blocks (carbon and hydrogen) as fresh biomass, they are not considered renewable because they have taken so long to develop.

In terms of environmental impact, there is a **big difference between** fossil **and renewable (fresh)** biomass. Fossil fuels influence the environment by burning them into the atmosphere, which have been stored beneath the Earth's surface for many millions of years. In contrast, the combustion of fresh biomass is neutral in terms of greenhouse gas emissions [101].

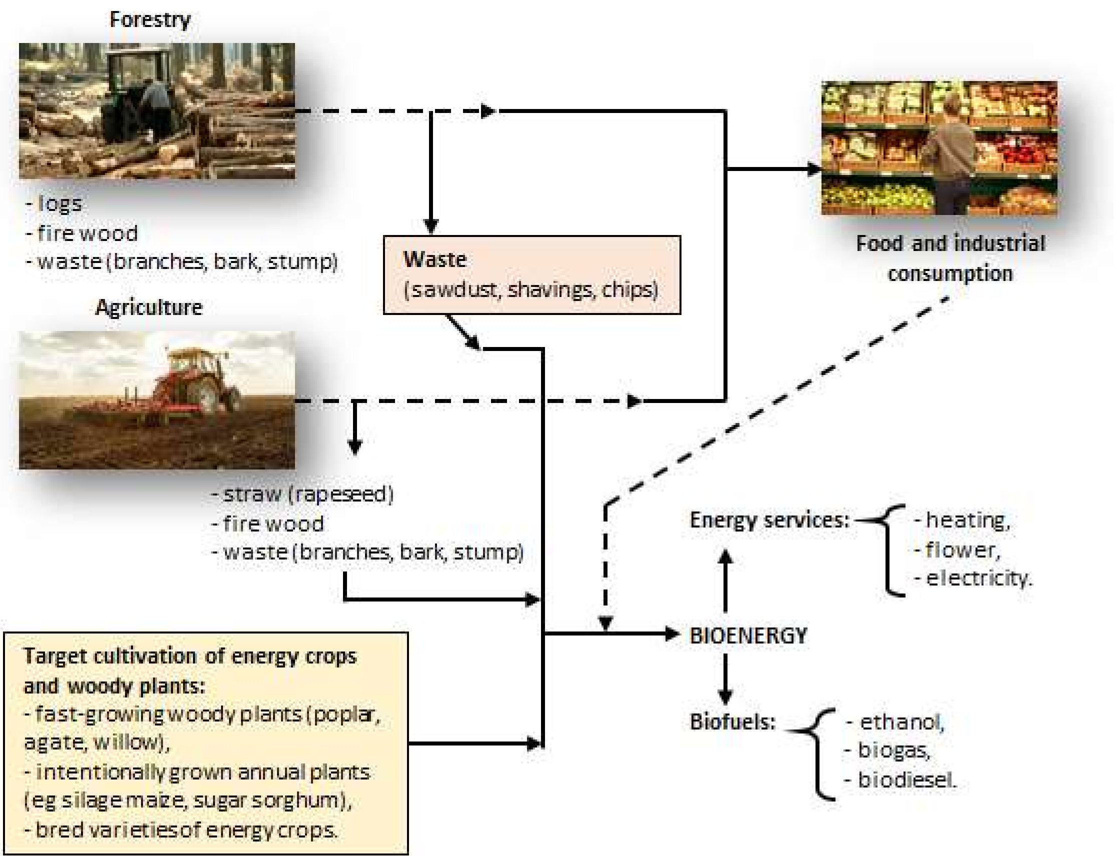


Fig. 84 Conversion of biomass into energy

The conversion of biomass into energy takes place in three basic ways (Fig. 84) [101]:

a) **thermochemical transformation:**
   - direct combustion,
   - pyrolysis,
   - gasification.

b) **biochemical transformation:**
   - methane fermentation + anaerobic extinction,
   - alcoholic fermentation + distillation.

c) **mechanical transformation:**
   - oil milling.

The most widely used fuel in the biomass category is **wood.** Wood as a fuel can take different forms - it can be used as piecework, as wood waste (e.g. in the form of chips - Fig. 85) or **pellets** (Fig. 86), **briquette** (Fig. 87) or it can be specially grown as **an** energy plant **(crop).**

Fig. 85 Sflaps

Fig. 86 Pellets

Fig. 87 Briquettes

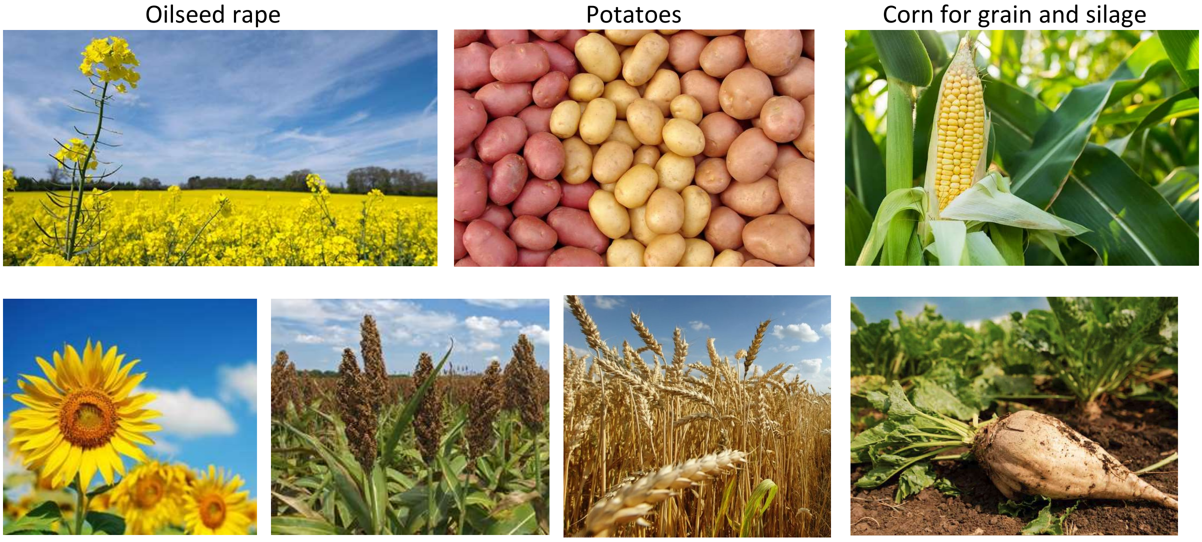
In Europe, the following crops can be used for energy purposes [101]:

- sunflower,
- different types of sorghum,
- reeds,
- Japanese wings,
- hemp,
- topinambury,
- kindman,
- sorrel,
- miscanthus - Chinese grass,
- Sudanese grass,
- rape,
- corn,
- cereals,
- polygonum,
- energy grass,
- energy plants - willow, poper.

Energy crops are broken down into [101]:

- **cultural crops also suitable for energy purposes**
  Some cultural crops are suitable not only for classical processing (e.g. feed, food, textile industry), but can be used as alternative energy sources (e.g. biofuel, thermal and electricity production) (Fig. 88),
- **genetically bred energy crops**
  Genetically bred energy crops are target grown to be used for pellet production, as fuel for direct combustion, as a substrate for biogas plants, or for the production of motor fuel in various forms. This group includes various permanent and annual crops (Fig. 89).

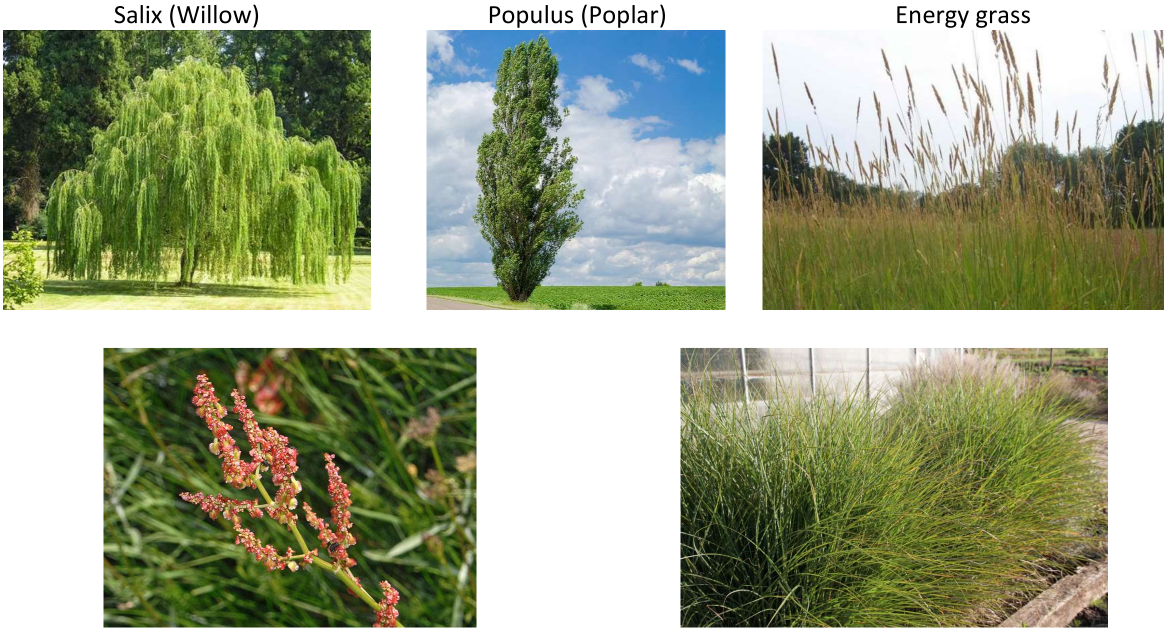
Oilseed rape Potatoes Corn for grain and silage



Sunflower Sugar sorghum Cereals Sugar beet

Fig. 88 Cultural crops

Salix (Willow) Populus (Poplar) Energy grass



Rumex (Docks) Miscanthus

Fig. 89 Genetically bred energy crops

The composition and calorific value of selected biomass species is given in Tab. 14.

Tab. 14
Composition and calorific value of selected biomass species

Title	Composition [%]							Calorific value (kJ/kg)	Thermal energy (kJ/kg)
	Water content	Content C	H content	Content S	Ash content	Content O	Content N		
Hemp	15,7	40	4,9	0,4	2,6	35,6	0,8	15725	17190
Hemp	7,8	41,3	5	0,1	1,8	41,2	2,4	14285	15723
Willow	42,85	-	-	-	-	-	-	10378	11400
Willow	5,2	43,8	6,7	0,1	1,3	44,6	0,7	18554	18681
Pellets energ. grass	0	46,7	6,5	0,1	5,0	41,6	0,8	17239	18652
Pellets energ. grass	**5,5**	**43,6**	**3,2**	**0,1**	**6,3**	**40,4**	**0,9**	**16700**	-

However, there are other sources that play an important role in the energy balance of many countries. This includes e.g. organic residues from agricultural production such **as straw** (Fig. 90).

Fig. 90 Straw [102]

Biomass is also **biogas** (Fig. 91) obtained from municipal waste dumps, wastewater treatment plants or manure from livestock production.

Biogas is a mixture of gases (Fig. 92), mainly CH_4 methane (50 - 70 %) and carbon dioxide CO_2. It arises in the process of expulsion of biomass without the presence of oxygen, as a result of metabolism of methane bacteria [101].

The same process that takes place in nature in the digestion of ingestors takes place in large and biogas stations by a controlled process. All bio-wastes are degraded over time, but without being used as a potential source of energy. Process-controlled biogas plants produce biogas (methane), which is used to generate electricity and, where possible, thermal energy or to produce methane [101].

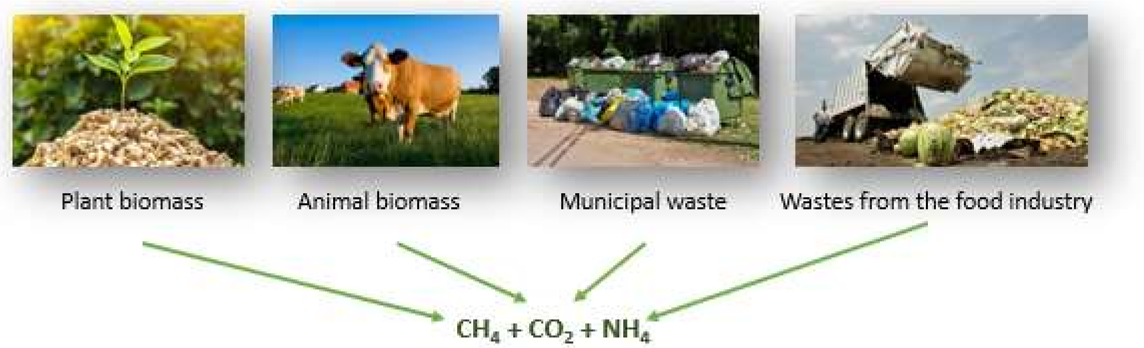


Fig. 91 Biogas

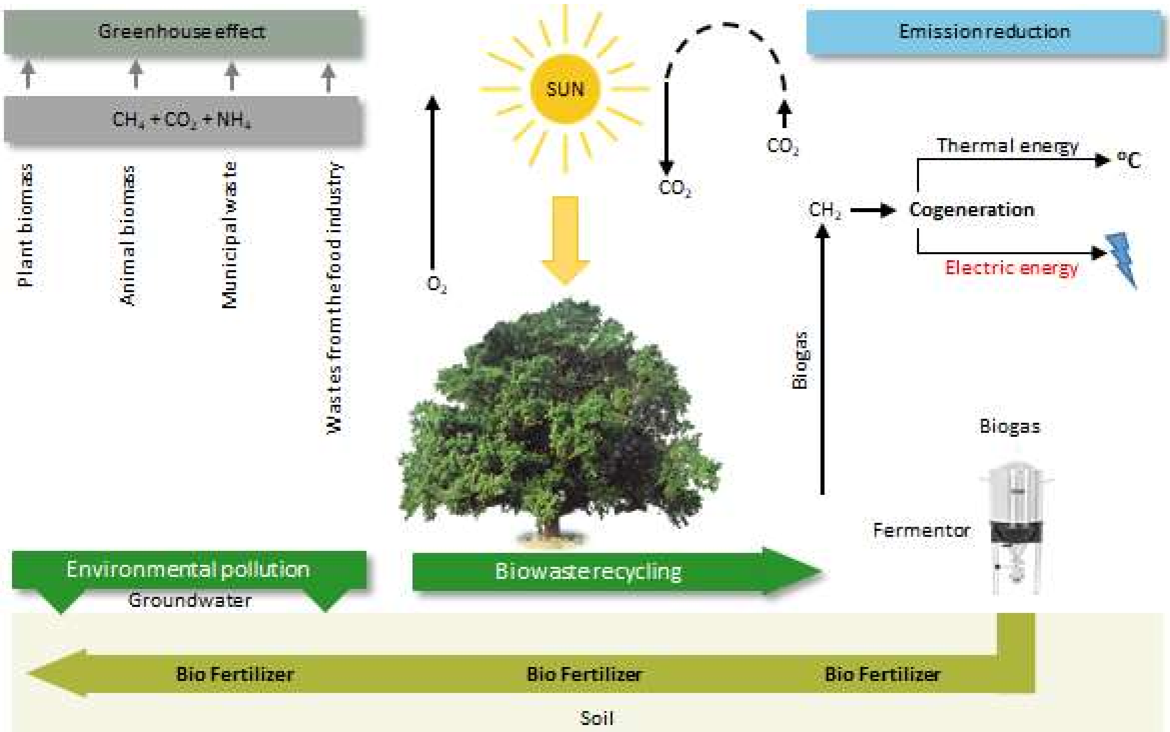


Fig. 92 Integrated bio-waste recycling cycle

Biogas is used:

- **without modification** [101]:
  - combustion in direct heating boilers,
  - generation and heat in the cogeneration unit (after de-sulfuration) (Fig. 93). In wet processes, 30 - 60 % of this heat is needed for the fermentor's own heating.

In dry processes, 5 - 10 % is needed. In the production of electricity, excess heat is generated.

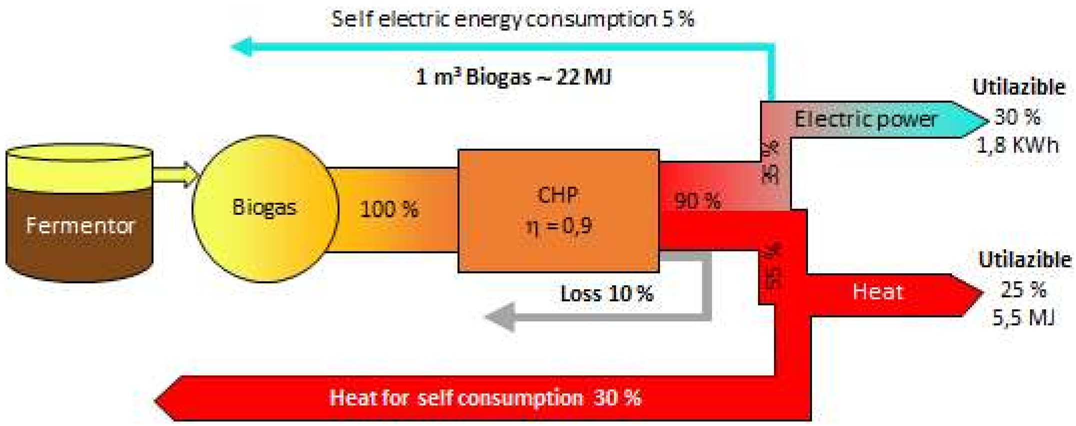


Fig. 93 Energy balance of biogas plant [103]

- **with treatment - after cleaning to almost 100 % CH_4**:
  - supply of biogas to the gas network or to heat producers,
  - as fuel for the propulsion of trucks and passenger cars, agricultural machinery.

In terms of reducing greenhouse gas emissions and climate change, all biotechnology is of paramount importance. Not only plants that absorb CO_2 from the atmosphere during their growth, but also the use of biogas consisting mainly of methane (CH_4), landfills or dung, contribute significantly to reducing emissions. Methane has up to 20 times more effect on the atmosphere than CO_2.

The use of biomass is also of great importance in terms of reducing sulphur emissions and limiting acidic gradients (acid rains), as its sulphur content is significantly lower than that of coal or oil. In addition, biomass can be mixed into coal to further reduce sulphur emissions in conventional power plants or boiler rooms [101].

The use of biomass for energy purposes also provides other environmental benefits. The most important are improving the quality of forests, waters or preventing soil erosion. The disadvantage of biomass as a fuel is that almost all types of crude biomass are subject to rapid decomposition under normal conditions. For this reason, few are suitable for long-term storage and, due to their relatively low energy density, the cost of transporting them is also relatively high. Therefore, roads are currently being sought to make the most of this energy source [101].

A simplified scheme for converting different types of biomass into energy is given in Fig. 94.

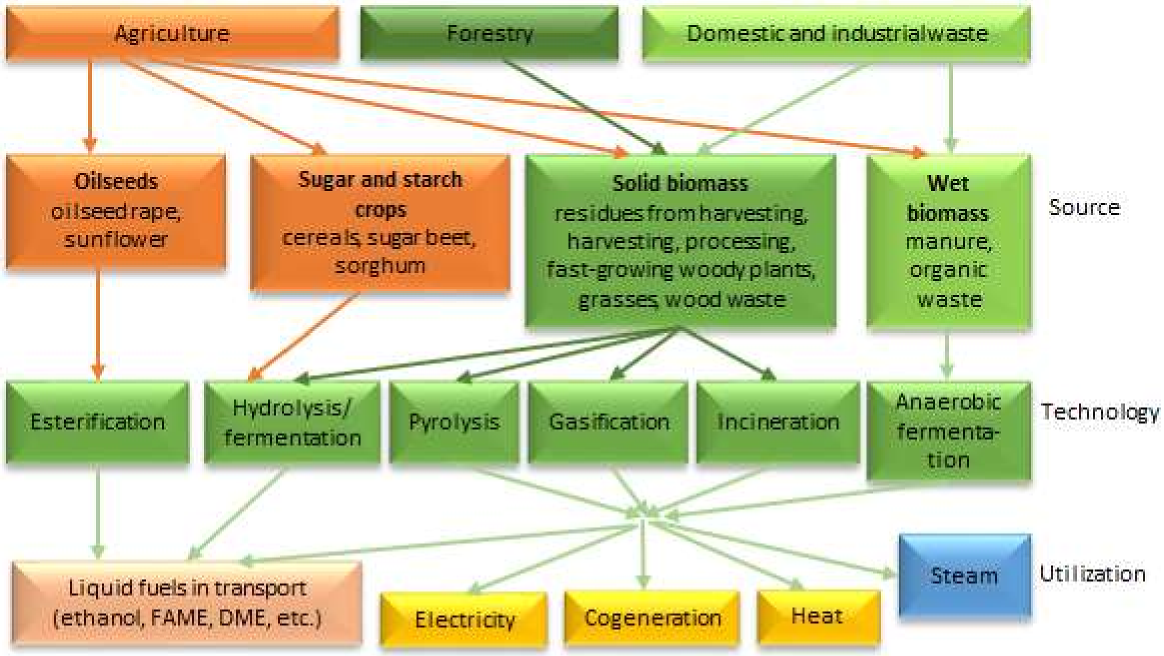


Fig. 94 Miscellaneous types of biomass

5.8 The Future of Natural Resources

In the context of the depletion of mineral reserves, it is necessary to look for new raw materials or new forms of use of existing ones. There are several ways to prevent the raw material crisis and slow down the depletion of current resources [104].

- **The first - is the search for raw materials outside** continents. Already today, 30 % of oil production is carried out from the bottom of the seas. At the bottom of the oceans are huge reserves of some important raw materials, such as iron and manganese ore. However, with the current technical equipment, we are not yet able to extract these ores effectively.
- **The second way is to use secondary raw materials**. Iron and paper have the largest share of recycling volume. Recycling not only leads to a slowdown in the utilization of raw materials stocks, but also has economic benefits and protects the environment. For example, much less labor and energy is needed to produce steel from iron scrap than iron ore.
- **The third form is the rationalization of the production process and the introduction of non-industrial technologies**. The aim is to manage industrial production so that the minimum material and energy consumption achieves maximum effect with a minimum amount of waste.

The most critical is the state of exhaustion in the area of energy raw materials. With today's consumption, current oil and gas reserves will last just under 50 years. It is therefore already necessary to look for alternative energy sources. Although they already exist, they will still have to wait for their mass use [104].

The biggest challenge facing 21-st century humanity is making mineral extraction as efficient as possible. Even with today's technologies, we process only about 10 % of raw materials.

Systematic research has found that, for example, the world's oil reserves are fifteen times larger than projected in 1950. For example, only Iraq has so much oil that it will be able to extract it in the 22-nd century [104].

The Greens like to say that today's pace of economic growth is unsustainable. It is claimed that "*limited natural resources simply will not let us go*". In fact, the amount of raw materials available to us is not limited as much by nature as by the level of science and technology, together with the opportunities for entrepreneurs to use new technologies in practice.

The limits of economic growth lie not in nature, but in the human mind, in its ability to constantly find new practices. An optical cable made of 65 kilograms of clay transfers more data than an equally long copper cable, the production of which consumes one ton of copper. It is more gentle for nature to send a letter to America by air mail or send it by e-mail [104].

But let's imagine that we're really running out of raw materials on earth's land, covering about one-third of the Earth's surface. There's still an ocean left. Stocks of mineral resources on the seabed are unimaginable underwater bearings arise in places of contact of continental plates. There are cracks in which heated water penetrates, which in the underground lysing from rocks iron, zinc, manganese, honey, sulfur, but also gold and silver. Under the Red Sea, there are about 95 million tons of ore. Of which half a million tons of copper, six thousand tons of silver and five thousand tons of gold. South Africa, the world's largest gold producer, does not export 600 tons of this precious metal per year. Moreover, unimaginable methane reserves have appeared on the seabed, surpassing coal, oil and natural gas reserves many times over. Plankton withdraws so-called greenhouse gases from the atmosphere and drops to the seabed after it has dead. These reserves can replace coal, oil or natural gas, but they can also be broken down into hydrogen and carbon as needed and used as an almost inexhaustible, nature-damaging source of raw materials [104].

We must realise that there is no such thing as natural resources in itself. Only by discovering the usability of a substance will it become a natural resource. Therefore, natural resources can constantly increase. Two thousand and fifty years ago, oil was not a natural resource because it was useless to people. People didn't know its use, and if they accidentally ran into oil rather than water while digging a well, they were furious because they didn't know what to do with black greasy liquid. You can only talk about the depletion of natural resources if we think in the minds of infinity. There is no doubt that the raw material base of mankind will one day become hydrogen instead of oil. Not only as a substitute for gasoline for cars, but also as fuel for thermonuclear power plants in the form of deutely. Unlike oil or coal, hydrogen reserves are inexhaustible. It's the most common element in the universe. **When are we going to move from fossil fuels to hydrogen?** The answer is simple: **when it pays off** [104]**.**

5.9 Nature´s Potential and Stress

In the primary position, the "*ecological crisis*" is understood as a fight to improve living conditions and protect natural wealth. Biological problems are assessed at this level mainly from a science or socioeconomic point of view. However, man came into conflict with nature, especially when filling and inguming material needs. In this regard, he is helping with technique. Industrial development has thus, in a sense, become the cause of gloomy ideas about the future of humanity. Without further development of industry and technology, further development of human society is not possible. It is therefore necessary to look for ways to promote and develop environmentally (environmentally) acceptable approaches in industry as well [1].

5.9.1 Ways of Using Nature

The primary economic activity, if it can be called economic, was the mining of wildlife wealth in the form of grain, fruit, meat, etc. However, this activity has not yet meant an intervention in nature that would endanger it. Nature was in a position to control it all.

The first intervention in nature was **the elimination of some species of** animals of the food chain that man struggled with. From that moment on, a person became responsible for regulation in nature.

The second important step **was the selection of certain useful plants.** A boundary has been laid between useful plants, useful animals and between harmful organisms and unnecessary plants.

The next step **was to build strong** housing estates and then increase them. The changes made in nature contrasted with geomorphology, e.g.: terraced soil, artificial lakes, river overlay, watercourse breakdown, ...

Stress for nature also means transferring organic matter from one production system to another.

A stronger form of destabilization of nature is if the climate changes by changing into the natural environment, an intervention in biology and chemistry. The order of stressful factors is approximately as follows [10]:

- elimination of carnivores,
- establishment of unnatural human communities,
- changes in original chemistry,
- the complete eradication of human communities,
- changes in physical conditions for the genus.

In all systems, there are mass interactions with climate, geomorphology, geochemia and vegetation under certain soil conditions. Vegetation fulfils two other tasks: it protects the soil from destruction, the action of the atmosphere, and protects a certain substrate, which forms a certain bundle with the associated form.

5.9.2 Limits of Usefulness

The economic use of nature is always associated with an energy attack. Excessive energy attack is always associated with disturbances in the natural raw material and energy flow. The associated profit targets a certain limit. That's one aspect of using nature. However, the use of nature has its natural limits. The second aspect is that the associated destabilisation can only be compensated to a certain degree by the self-healing power of nature. So it has its natural limits. If they are exceeded, the system will be broken down and thus useful. The limits of this fact depend on the nature of nature use, as is the economic result. Every system has a slight resistance force against the stress just imported. The response potential of ecological elements to economic stress is given in Fig. 95. Profit-making comes to the fore with each new intensive type of use of nature (Fig. 96) [1].

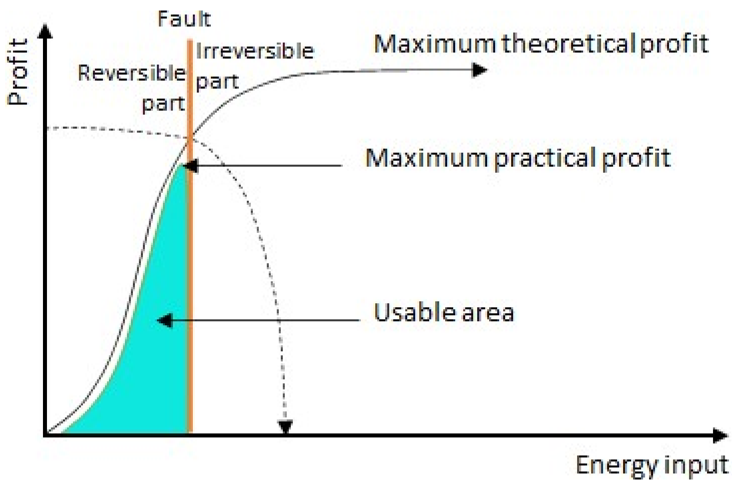


Fig. 95 Reaction potential of ecological elements to economic stress [105]

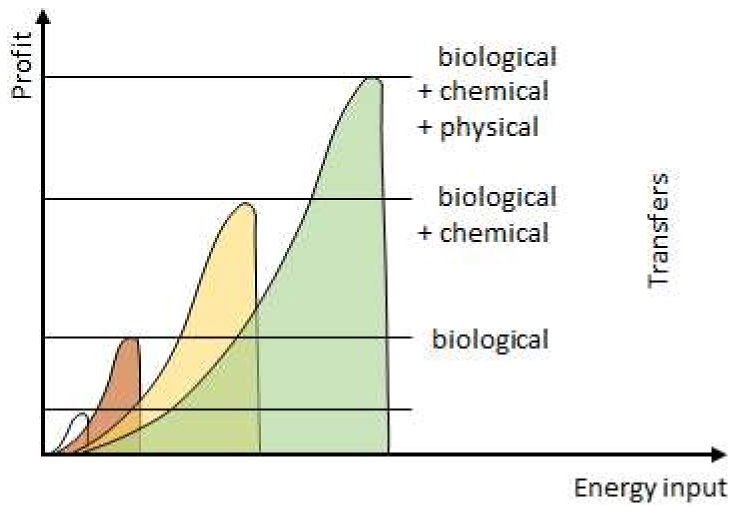


Fig. 96 Stress intensity, profit and break in the economic system

5.9.3 Integration of Economics and Ecology

The economic use of ecological systems over long periods of time is possible provided that economic stress does not exceed the permissible limits.

Economic usefulness can be obtained from all ecological elements starting from physical to geochemical to diverse biological [1].

A combination of these elements can lead to a large selection of options for their use. On the opposite side stands the element man. The size of the population is increasing, their need sare increasing and they are being integrated into a single human need. However, the need can be turned into stress when technical capabilities and the necessary energy are not available. The needs are then variable in relation to the needs system and contribute to the expected raw materials and with them to the expected profits.

The choice of ways of using nature must be taken carefully within the framework of economic and ecological concepts, taking into account its future use. An environmentally sound economy must cause qualitative improvements in exploitation methods from the ground up and minimize the associated stress potential as much as possible.

Thus, an active solution to the consequences of environmental pollution is to reduce its degree to the threshold of nature's absorption capacity. Achieving this objective is a function of the cost of protection. In order to find a minimum of ecological costs, it is necessary to transform the cost curves so that the costs of protecting the environmental benefit, like damage, are a function of the degree of pollution [10].

The Fig. 97 confronts the cost curves with the damage curves from which the ecological cost **curve is derived (E = S + N).**

The minimum environmental costs are at the point to which the damage and cost values correspond, point S and N. This minimum can be **called the economic optimum of pollution,** which represents a minimum ecological burden which, on the basis of available technological knowledge and in line with other socio-economic development objectives, can be considered economical.

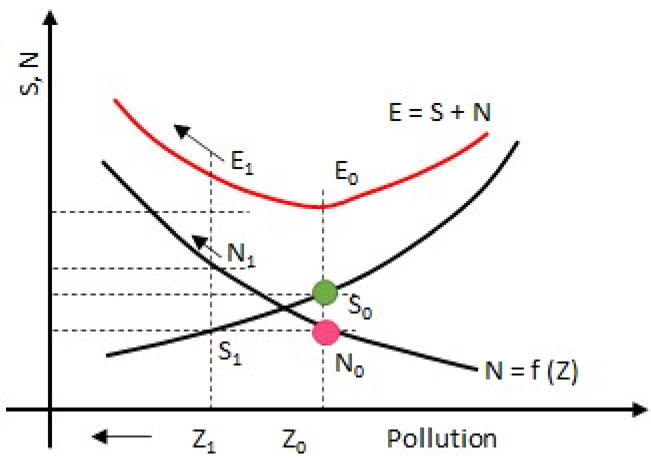


Fig. 97 Ecological cost curve [105]

5.10 Ecological conditions

In each natural ecosystem, the existence (action) of two ecological states can be observed, namely [1]:

- **ecological stability** (homeostasis),

- **ecological stress** (ecological crisis, environmental disaster).

5.10.1 Ecological Stability

The state of the ecosystem when it is not degraded is called homeostasis (dynamic balance in the system). Ecosystem homeostasis is a situation where regulatory mechanisms operate at both individual and system level. In the ecosystem, it is such a circulation of substances and energy that maintains itself and does not need external intervention or popping. Homeostasis in the ecosystem is characterized by interaction of several factors (abiotic, biotic and anthropogenic). With the permanent action of some of the ecological factors, the deviations are not settled and the system moves to another state. Homeostasis is the evolutionary stability of the system. The state of when the principles of homeostasis apply in the ecosystem is called the succession of the **ecosystem.** From the point of view of succession, the ecosystem can be [10]:

- immature (small stimulus leads to dynamic imbalance),
- mature (dynamic equilibrium is disturbed by a great stimulus),
- at risk.

Succession changes in the ecosystem may be [10]:

- suddenly (the system is severely damaged or disappears),
- gradual,
- periodic,
- random,
- cyclic,
- directional,
- adoptive (climate change),
- transferred (changes induced e.g. by large-capacity holdings).

In terms of duration, succession changes may be:

- **primary** (long-lasting process, e.g. several centuries),
- **secondary** (short-term process).

Most ecological strategies are based on the assumption that if the external stimulus ceases, the system will return to its original state. The conditions for this return to "*normal*" are determined by the type of stability of the system [1]. This may be manifested by:

- **resistance of the ecosystem, the ability** of the system to defend itself during the action of a disruptive factor,
- **the resiliency (flexibility) of the ecosystem, the ability of the system to return to normal after the end of the interference factor (the measure is the time at which the** restoration occurs).

Stabilisation mechanisms in the ecosystem operate only within certain limits. If they are exceeded and if the stress lasts for a long time, the ecosystem will change to another or disappear. What are the limit limits, however, is not known.

5.10.2 Ecological Stress

The ecosystem's response to the action of the factor is called ecological stress. It is a state of the system in which all protective or remedial processes are mobilised. The result of the response depends on whether it is a one-time or permanent action of factors. With a single action, there may be three possible forms of adaptation [1]:

- **perfect,**
- **partial,**
- **no.**

With the permanent action of factors, there is [1]:

- **alarm reaction** (relatively rapid, unexpectedly large, disappearing system response),
- **resistance stage** (slow response of the system to stressors, the system is temporarily resistant),
- **depletion** stage (exceeding ecosystem adaptation capabilities).

Stress-inducing factors in the ecosystem are called **stressors**. Stressors can be **inherent (internal)** or foreign **(anthropogenic)**. There is no ecosystem capable of permanently resisting all foreign stressors. Two states must be distinguished from the point of view of the effect of stressors on the stability of the ecosystem:

- **normal exposure to stressors which** it induces:
    - insignificant changes in the ecosystem,
    - cyclical or short-term fluctuations in ecosystem characteristics,
- **extreme effects of** stressors, manifested by a critical or catastrophic change in the ecosystem.

The extreme action of stressors may result in [10]:

- **environmental crisis,** i.e. a situation where the adaptive capabilities of the system are close to the achievable,
- **environmental disaster,** i.e. a situation where the conditions for the reproduction of the ecosystem are disappearing.

Specific stressors are stressors civilization (population explosion, raw material extraction, air pollution, explosion of impacts, etc.). Predicting the response of the ecosystem to the action of civilization stressors is very difficult, since [1]:

- major civilization stressors are permanently grading,
- the effect of the main stressors (synergy) multiplies,
- stressor balance is incomplete (many stressors are still unknown),

- the intensity of the stressors is not decisive, but the intensity multiplied by the duration of action and this is usually unknown,
- in the long term, it is not possible to make forecasts on the basis of linear extrapolation.

On a global scale, the issue of the global ecological crisis at the OSN was first discussed in 1968 [106]. For the first time in the history of mankind, a global crisis has arisen involving both developed and developing countries - **the human environment crisis.**

The causes are [10]:

- rapid growth of the world's population,
- disturbed balance between technology and the environment,
- deterioration of the situation of agricultural land,
- chaotic growth of urban settlement,
- reducing the area of space needed,
- increasing risk of disappearance of animals and plants.

No crisis in history has highlighted the interdependence of nations as much as the environmental crisis. The only rule remains: ***"The world is only one"***, indivisible and not mutually dependent, it is threatened by the unplanned, growing activity of man.

6 BASIC COMPONENTS OF THE ENVIRONMENT - WATER

Water covers more than two thirds (about 71 %) of the earth's surface. Its volume is estimated at 1,4 billion km^3. A substantial portion (about 97 %) is salt water (seas, oceans) and only represents about 3 % of fresh water, which is absolutely essential to ensure life on earth. 2 % of fresh water is tied up in glaciers and permanent snow. Usable rest of freshwater represents less than 1 % of all water on Earth [85].

Water (H_2O) is a chemical compound of oxygen and water. It exists in the gaseous phase (steam), a liquid (water) and solid (ice). The water creates with other compounds crystal structures of minerals [53, 111, 112, 113].

6.1 Functions of Water in Nature

Water (H_2O) is an essential part of the environment and is vital for life on the Earth. From this perspective, but mainly in terms of human, is irreplaceable water and performs the following functions [110]:

- **biological,**
- **health,**
- **cultural and aesthetic,**
- **production (agriculture and industry) and transport.**

The biological function of water lies primarily in the fact that water is practically one universal solvent in a world of living systems - organisms. The function of water as a "*solvent*" is applied in a number of mineral salts, which are components of the irreplaceable the outside and serving as an ion source to keep the metabolic process, and thus the life of organisms. In higher plants, a supply of ions takes place through the root system. The animals, firstly by drinking water, containing the substances in a more or less concentrated form, but especially by a solid diet containing the corresponding salt. Reception must be regulated in some way that surpluses were excluded in time to avoid possible damage to the body [2].

From the ions, which are strictly necessary for the life of most organisms, it should be mentioned in particular Na+, K+, Mg^{2+}, Cl^-, SO_4^{2-} , which can be connected with ions of the calcium and phosphorus. In addition to this basic group, there are a number of ions, which are necessary for a particular group of organisms. The need for the ions Fe^{2+} for vertebrates and therefore humans, which is necessary in the formation of hemoglobin and the like. Very important is the so-sufficient "*Trace elements*" (J, Cr, Cu, Mo, Se, Zn) [110].

Receiving his own water in the body is basically going under osmotic pressure. Together with the water molecules the organisms diffuse all that is in aqueous solution. If it contains water as well as substances harmful to the environment, pass these pollutants in the body at the same way. **Water is therefore an important intermediary** in the food chain between internal and external environment and living organisms [110].

The basic **function of water for plants** is based on [2]:

- dissolving plant nutrients (salt) in the root zone,
- transport of nutrients in the plant,
- participation in photosynthesis,
- hydration enzyme,
- regulators thermal properties.

Claims of crops for water, essential for human nutrition are significant. To create 1 kg of organic matter (dry matter as biomass) is required from 400 to 500 liters of water.

In animal **water ecosystems perform** the following functions [110]:

- it is an important part of protoplasm,
- active in the gastrointestinal tract as a solvent,
- participates in the metabolism,
- it is an important component of body fluids,
- for some animals directly to their environment (about 15 % of all animals are aquatic organisms).

The body of the human being, as the species, creates in the infancy approximately 80 % of water, in the old age is apr. 50 - 60 %. During aging, the water decreases.

The health function of water - consists in the fact that it is irreplaceable for ensuring personal and public hygiene of a person and for its wide application in recreation. It is used for drinking, cleaning, waste removal, heating and the like.

Culture and aesthetic function - it is beneficial for the beautification of the landscape and settlements. It is an important factor from the point of view of landscape architectural creation.

Production and transportation function - water is used in many areas of industry (cooling water, technological water, etc.) and agriculture (irrigation, spraying, drinking, etc.). The water of rivers, seas and oceans enables relatively cheap transportation of goods.

In the case, water occurs in three states: as a **liquid**, which at a temperature of 0 ^{o}C and a pressure of 100 kPa turns into **ice**, and at the same pressure and temperature of 100 ^{o}C into **steam**. In the case, there is an unchanging cycle of water (Fig. 98), the so-called hydrological cycle.

The water of the rivers flows into the seas and oceans, the water from the land of the seas and oceans evaporates, the evaporated water condenses and falls on the earth's surface in the form of rain. A large and a small water cycle can be distinguished. There is a great circulation between the waters of seas, oceans and land [85]. Due to the action of the Sun's thermal energy, water evaporates from the water surface (but also from the surface layer of the soil, from the leaves of plants and from the skin of animals). Water vapor rises, cools, condenses into tiny droplets, forms clouds that move from one place to another and finally fall back to the earth's surface as precipitation. A small water circulation is said to occur when there is a circulation of water within the oceans or the land [85].

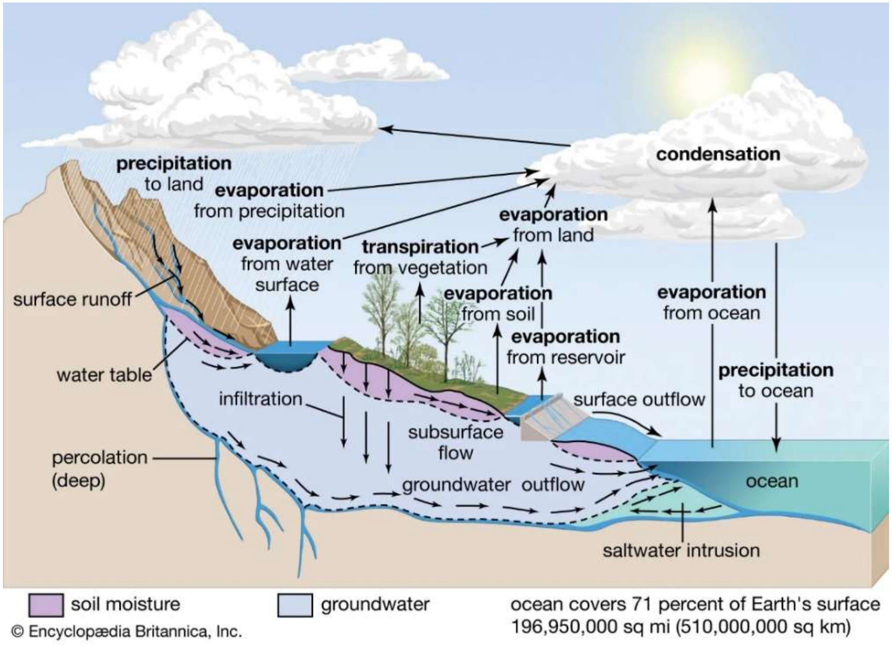


Fig. 98 Small and large water cycle [107]

About 50 % withholding water is soaked into the ground and is used it to plants or is evaporated back into the atmosphere. Approximately 40 % of stormwater is mixed with surface water streams, rivers, ponds lakes [2]. Only about 10 % of precipitation water is soaked into the soil and changes in the groundwater (Fig. 99). All water in the biosphere, including water vapor in the atmosphere is called the **hydrosphere.**

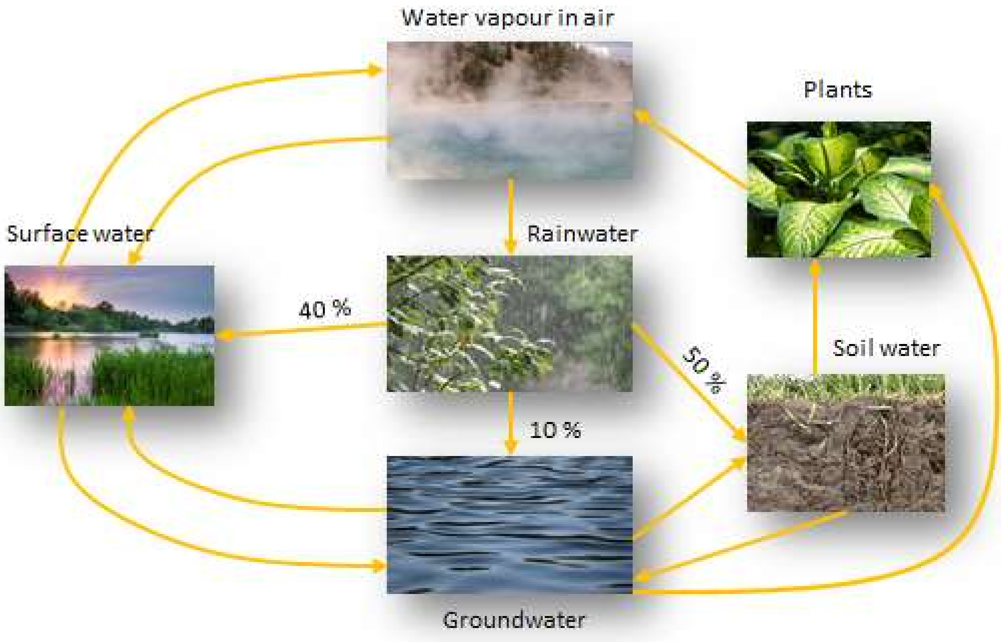


Fig. 99 Stormwater and its transformation

6.2 Sensory Properties of Water

The properties that affect on the human senses - **temperature, taste, smell, color, transparency.** The water temperature depends on its type. The surface water temperature is influenced by land and air. For the ground water temperature depends on the depth of the layer, from which the ground water comes from a water velocity. The optimum temperature of drinking water is 8 - 12 °C [110].

The water temperature is changed with the air temperature. In deep lakes and dams are several layers with different water temperature. This phenomenon is called **heat stratification**. The top layer of the water is changed at the same time with the air temperature. Below, it is the middle layer, where the water temperature changes abruptly. Below this is a lower layer having a stable temperature and lack of oxygen [110].

The taste of water is conditioned by the presence of substances, which are to receive water naturally or are the result of pollution. It affects the taste of the presence of iron, manganese, magnesium, zinc, copper, chloride, sulfate and the like. Higher salt content makes an impaired taste. Excess water makes some elements and typical coloration. Iron stains the water to a rusty, it gives her unpleasant bitter taste. Water with an admixture of manganese is red.

Smell is a property of water caused by volatile substances acting on humans. Odor sources are [110]:

- **Primary agents** - substances that are natural components of water, substances of biological origin substances from sewage and industrial wastewater,
- **secondary agents** - e.g. technological water treatment - chlorination.

Color - clean water is colorless, in thick layer of blue. The presence of the finely divided salts into the water is dyed to green, yellow- iron compounds, and the like.

6.3 Distribution of Water

Water is generally distributed in two ways:

- by origin,
- according to usage.

By origin a distinction [88]:

- **rainwater** - rain, snow, drizzle, dew, frost. Withholding water is very clean. It is the water produced by the distillation of natural, in their journey to tear off air contaminants occurring in the atmosphere. Because the air travels through the water just short, not enough is very dirty. Water is soft, it contains little dissolved solids. The temperature varies with the air temperature.
- **surface water** is water brooks, streams, rivers, ponds, lakes, dams, each word water on the surface. It is a special type of sea water. Surface water originates from atmospheric and groundwater. Component which predominates determines the final

properties. Groundwater gives it a cool, delicious taste, hardness, atmospheric water softens it, brings it into the soil, changing its physical and chemical properties. On surface water and air quality act. Surface water is usually soft to medium-hard. The temperature of the air changes with temperature, the pH is stable.

Sea water is a specific type of surface water. This water is the amount of dissolved salts, which cause its characteristic taste [88].

- **Underground water** is the most precious quality of their drinking water supply. It arises from surface and rainwater, which penetrate the soil and enrich the elements of salt, get rid of impurities. Underground water can also be divided into different types, each type has its characteristics. They are the vadose - shallow water, juvenile water, pore water, fissure water, karst water. Properties of the groundwater determines the chemical composition and physical properties of the soil layers, which water passes, and the time, which the water is in contact with the ground. Groundwater is usually hard, with a pH neutral or slightly alkaline. It has a constant temperature. A special type of ground water are **mineral water**, the waters containing in 1 kg of water over 1 g of dissolved substances, and 1 mg of sulphide inorganic material 5 mg of iodine and 10 mg of ferrous iron. If the underground water warmer than 25 °C - 50 °C, they are **thermal water** at a temperature of 50 °C talking about the hot **spring waters**.

By use of a distinction [110]:

- **drinking water**, which characterizes the properties of Slovak Standard STN 830611. It is a wholesome water which may not be the cause of diseases. Must not contain toxic, radioactive, biologically harmful substances, it must contain elements and substances necessary for the organism.
- **potable water** should not contain substances toxic to human health. It must be also biologically harmless. Its physical and chemical properties may be inferior to that of drinking water. It can be used for washing, bathing, washing, watering the animals, but for drinking, food preparation and medicinal products for dishes to be used herein is not appropriate. The characteristics of potable water and its use, the authorities sanitary services.
- **process water** serves exclusively the needs of industry and agriculture.

6.4 Water Pollution

The historical evolution of man's relationship to water has gradually various aspects. In the first period of civilization it has had the role of irrigation water, and later was the dominant **transport and energy**. Until recently due to rising population density, increasing housing culture and massive industrial development, shall have the meaning **health - hygienic** and **technological**. Along with these new meanings, the focus in addition to the quantitative dimension and the qualitative issues: the issue of **water quality** in its purity [108].

Pollution (contamination) of surface waters and groundwaters mean any change in the physical, chemical and biological properties compared to their natural state, that partially or completely prevents their simultaneous use, worsens the living conditions for aquatic organisms, possibly increasing demands on water treatment technologies.

Depending on the extent of contamination are identified [108]:

- **gradually increasing pollution** - which reaches the maximum permissible value, but compared to the intrinsic value is the greater,
- **pollution** - that exceeds the maximum permissible values.

According to the time interval is allocated to pollution [108]:

- **emergency** - which is unexpected and potentially disastrous environmental consequences (e.g. a car accident with harmful substances, and the like.),
- **permanent** - caused mainly by waste water from industry (organic and inorganic substances with toxic effects, organic and inorganic substances toxic substances) and agriculture (silage juice, urea, manure, etc.)**.**

6.4.1 Groundwater Pollution

Pollution of groundwater pollution depends mainly on the natural environment, i.e. from soil, rocks, water, atmosphere and precipitation, and the handling of substances damaging water. The main cause of pollution of groundwater include [3]:

- leakage of waste water by leakage from drains, cesspools and sewage facilities,
- the discharge of waste water and special water into the rock environment, the method can be implemented only in exceptional cases,
- operating, emergency, and other releases of harmful substances in racking, expenses, handling, storage and use,
- leaks from poorly secured landfills for municipal and industrial waste, tailings, storage of fertilizers and chemicals to protect plants and other substances,
- leaks of hazardous liquid waste facilities of agricultural production (silage troughs, etc.)
- leaks solutions used in mining, exploration and other activities,
- washing out of substances from the soil and rocks,
- polluted rainwater infiltration,
- infiltration of polluted surface water.

Groundwater is less vulnerable to contamination than surface water, the pollution effects last longer in comparison with surface waters. Cleanup of the ground takes several months, even years been liquidated sources of pollution. Groundwater contamination often be delayed and can detect only when the contaminated zone saturated [110].

The source of groundwater pollution can be [3]:
- waste water,
- pollutants in underground water,
- other sources of pollution.

According to the Slovak law No. 364 / 2004 C.l. about water (Water Act), the **waste water** are considered water used in residential areas, villages, houses, factories, healthcare facilities and other facilities unless the application have altered quality (composition or temperature) as well as water from them, flows as may endanger the quality of surface water or groundwater. Waste water is water seepage from tailings and waste dumps [110]. The Act defines two conditions to allow the water to be waste. The first condition is **altered water quality**. In the second case in other waters condition that the waters may threaten the **quality of surface water or underground water**.

According to the pollution of the waste water to distinguish [3]:
- sewage (waste water from households, kitchens, toilets, ...),
- industrial (waste water from the production processes in industry),
- agriculture (waste water from agricultural production),
- precipitation (water discharged into the sewer system from the streets, roofs and public spaces where polluted by washing the surface will deteriorate their quality),
- special (mine water, warmed, mineral and thermal, hospitals, ...).

Currently, the most common pollutants in underground water include metals (Hg, Pb, As, Cd, Cu, Cr, Zn, Ni, Ba, B, Sb), oil products, agricultural waste, substances used in farming and various chemicals inorganic or organic nature (e.g. phosphorous and nitrogen compounds, radionuclides, detergents, phenols).

The number of substances that can pollute underground water rising steadily. Recent comparisons of quality of underground water point to the fact that you can not underestimate the impact of waste dumps and tailing ponds, sludge and microbial contamination.

Groundwater protection can be divided in terms of solutions to two spheres [3]:
- **primary** - active protection,
- **secondary** - passive protection.

The **primary** objective **of protection** is to prevent the ingress of contamination to groundwater. Primary protection of groundwater includes various activities (research, technical - organizational arrangements and principles), civil structures (catch basin, drainage, etc.) and construction - technical measures (protection against corrosion, alarm, etc.), Followed by legislation, planning and elimination of pollution sources in exploited areas and areas with promising sources of underground water, as well as buffer zones and monitoring network.

Secondary protection locates pollution in a particular area, to apply at large sources of pollution, which has already occurred to the pollution of underground water. To include secondary protection, here belongs emergency preparedness, material - technical and staffing. The above concept of protection is reduced rather on hydrogeology. Secondary protection should be of a temporary function. In fact, rehabilitation is a secondary protection.

6.4.2 Pollution of Surface Water

Surface waters are the source of drinking water and used for recreational purposes, fish farming and the like. At the same time, however, are recipients of sewage, industrial and other wastewater. Draining of the efluent waste water violates the biological balance in the recipient as well as their ability to self-clean. Discharges affecting the quality of surface water in terms of chemical, hygienic and aesthetic changes in water and are harmed public interests (public health, mortality of fish, etc.) [13].

The water in the river (recipient) may be by visual assessment "*clean*" or "*dirty*". That subjective assessment does not correspond to objective reality. The definition of "*clean water*" has a number of problems. The content of the concept is defined by the World Health Organization (WHO): **"*The river is contaminated, where the composition of the water changed as a result of direct or indirect human activity so that it is less suitable for some or all of the purposes for which are water in the natural state*"**.

From the aspect of the type of pollution and contamination of surface water can be divided into primary and secondary [13]:

- **Primary pollution** is caused by the substances that are present in the waste water optionally modifying some of the properties and can be divided into:
  - **contamination of inert materials**,
  - **of contamination by organic substances,**
  - **pollution of inorganic substances,**
  - **of bacterial contamination,**
  - **of radioactive pollution.**

- **Secondary poisoning** can be expressed as subsequent excessive development of some organisms, some of which may be pathogenic. Typical examples include [13]:
  - **about eutrophication,**
  - **of thermal pollution.**

6.4.2.1. The nature and Characteristics of Pollutants

Surface waters (but also the ground) can be, as already mentioned earlier in this chapter, contaminated with plenty of organic and inorganic substances. Contamination may be committed by bacterial, radioactive, and finally the physical (temperature, pH, electrical conductivity, and the like.) [109].

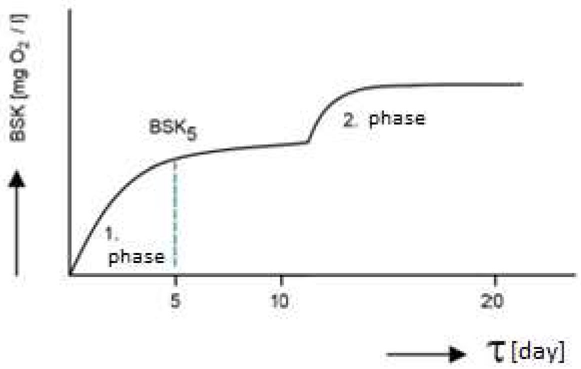
The main indicators of industrial, agricultural and municipal pollution include [109]:

- **Organic substances**. The waste water is present in a number of different organic substances. It is not possible to track and fix separately. Since they are capable of oxidation, it expressed their sum amount of oxygen consumed for their complete oxidation. Organic substances can be oxidized either chemically or biochemically.
- **Chemical Oxygen Consumption (CHSK**) indicates the amount of oxygen required for oxidation of organic substances, strong oxidizing agents ($KMnO_4$, KIO_3, $K_2Cr_2O_7$). For oxidation lays down certain conditions (oxidation time, temperature, acidity environment, etc.). Recently, the most commonly used $K_2Cr_2O_7$ oxidation in an acid medium, referred to as CHSKCr. Less frequent is the oxidation by $KMnO_4$ known as CHSKMn.
- **Biochemical oxygen consumption (BSK Slovak, BOD English, BSB German**) - organic substances characterized as BSK_5, is the amount of oxygen consumed by aerobic biochemical decomposition of organic matter present in the water for 5 days under standard conditions. Five daily consumption of oxygen was chosen as the standard, because the water in the River Thames in London flows to the sea for 5 days. Biochemical oxidation of organic substances is therefore in a natural way in the longer period of time. Chemical oxidation takes place on the other hand the absence of living organisms immediately and drastically with strong oxidizing agents, thus chemically cleaned. In practice, therefore, it has a higher CHSK value than oxygen consumption BSK.

The biochemical decomposition of organic substances in water takes place in two phases [110]**:**

- **In the first stage**, mainly to remove carbonaceous substance. This decomposition takes about 20 days (BSK_{20}). Depletion of carbonaceous material usually takes place immediately after the organic pollution. In the event that, initially on the adaptation of microorganisms for organic material, there is a short delay (soak) (1 - 2 days), which is called – “*Lag*” phase.
- **In the second phase** (starting to 10-th day) is removed nitrogenous substances and their degradation is not completed within 20 days. In practice, however, it considered the decomposition of organic materials of all completed in 20 days (the depletion of 99 %). In practice, usually determined as indicated above, the loss of oxygen in 5 days (BSK_5).

If the necessary conditions are satisfied (in particular, the amount of O_2 and pH), the degradation of organic matter takes place in the waters of the approximately the same time as the standard course of their bacteria should schedule. Within 20 days run out to the target and break down organic matter is completed. Fig. 100 [109] summarize the biochemical degradation shown schematically by mathematical relationships for computing.



Mathematical expression of this curve is the function y = f (L, τ)

Where:

y ... BSK change over time, mg O_2/l
L ... overall (final) BSK, mg O_2/l
τ ... time

General dependence BSK expressed Streeter-Phelps equation:

$$y = L(1-10^{-K\tau})$$

K ... The temperature dependent constant

0°C – 0,040
5°C – 0,050
10°C – 0,063
15°C – 0,079
20°C – 0,100
25°C – 0,128
30°C – 0,158

In practice, the calculations are to be found:

BSK_2 = 0,54 BSK_5
BSK_{20} = 1,46 BSK_5

Fig. 100 Schematic representation of the course of BSK_5 versus time [109]

The insoluble substances (IS) - are the solid and the suspended solids, which are entrained by water, moved or floating on the surface level. Insolubles determined by water filtration and drying up the residue at 105 °C to constant weight [109].

For waste water treatment containing IS used conventional devices such as sieves, screens, the arresters settlers. The modern methods include filtration, coagulation, and the magnetic.

The Soluble Substances (SS) - are substances that remain in the effluent in the sample to evaporate, drying and annealing at 600 °C to constant weight. It is mainly inorganic dissolved salts (essentially a metal cations and acid anions). For a group of dissolved inorganic salts is taken abbreviation RAS. Increased content SL causes salinity (salinity) of water. It is expressed in mg/l, g/l or parts per thousand - ‰.

The average salinity of the seas and oceans is about 35 g/l. It varies in a very wide range, e.g. Baltic Sea 7 g/l (or 7 ‰), the Black Sea from 11 to 13 g/l, the Adriatic Sea from 30 to 35 g/l and the Dead Sea 70 g/l.

SS removal of water, in contrast to IS very complex and requires the use of a technique of great economic and technological content. Technologies include distillation, membrane methods (reverse osmosis and electrodialysis), ion exchange (ion exchangers), etc.

Hydrocarbons - established as a non-polar extractable substances (NEL). For substances extracted of water without polar extractives substances (EL), for example. fats. Their separation is performed in a standardized way.

The reaction of water - pH is expressed. A value of pH = 7 expresses a neutral environment, at pH > 7 an alkaline environment. Emission standards for the discharge of industrial waste water are set within the range pH 6 – pH 9.

Water temperatures - increasing the temperature of the water is mainly reduces the solubility of oxygen in the water and to stop stimulating the biological processes of organic matter. Fish welfare temperature affects mostly indirectly [110].

The concentration of pollutants in waters is expressed in units of mass based on a volume basis (usually in 1 l), namely: **g.l^{-1} mg.l^{-1}, μg.l^{-1}** or when highly toxic substances in **pg.l $^{-1}$**. Mass unit ppm for pollutants waters has value:

$$1\ ppm = 1\ mg.l^{-1}\ (1\ l = 10^{6}\ mg) \tag{6.1}$$

When radioactivity indicators in **Bq.l^{-1}** (Becquerel per liter), or. **pBq.l^{-1}**. Water reaction is expressed in the **pH** scale. The total acidity of alkalinity and then the amount **mol.l^{-1}** respectively the **kmol l $^{-1}$.** For biological and microbiological indicators **KTJ.1 ml^{-1}**, meaning the number of colony forming units (number of colonies) of 1 ml. KTJ in this case, is the colony forming units.

When calculating the indicators of permissible pollution of surface water in waste water discharges starting from the mixing equation having the following form:

$$Q_r = C_r + Q_o\ .\ C_o = (Q_r + Q_o)\ .\ C_v \tag{6.2}$$

where:

Q_r – water flow in the recipient [m^3.s^{-1}],
Q_o – the amount of wastewater [m^3.s^{-1}],
C_r – concentration of pollution in receiving water [mg.l^{-1}],
C_o – concentration of the pollution in the waste water [mg.l^{-1}],
C_v – final concentration of pollution in receiving water [mg.l^{-1}].

6.4.2.2. Quality of Surface Water and the Method for Their

Evaluation of surface water quality in practice based on the determination of representative indicators, and their choice depends on how you use the monitored surface water and the presumed pollution.

Quality of surface water during the year vary widely, not only in time, but is also different in the different layers of water. Flow classification means standard sorting according to the quality of water flows. Indicators (indicators) reflect the physical state, chemical composition and biological settlement of water [110]. They are divided into:

- **individual** (Fe, Mn, N, P, and the like.),
- **group** (BSK, CHSK, insoluble substances, ...).

For practical use, the indicators are staying in the **criteria** (e.g.: criteria oxygen regime of water is set the following indicators: O_2 concentration, temperature, BSK_5, $CHSK_{6r}$, TOC and saprobity). The limit value indicators is **normative**. It is a set of norms **classification**.

In a qualitative balancing of surface water comes from surface water quality assessment:

- According to Slovak Standard STN 75 7221 [115],
- The Slovak Government Regulation no. 296/2005 Z.z., which establishes the requirements for achieving the professional status of waters.

The basis of surface water quality assessment is a summary of classification results in Slovak Standard **STN 75 7220 "*Water quality. Surface water quality control*"** [114], which assesses water quality parameters in 8 groups (Tab. 15). Water quality is classified separately for each indicator of the relevant indicators. The inclusion of water quality according to each indicator to a class of water quality is done by comparing the calculated characteristic value of this indicator with an appropriate system of the limits (for pH interval values). The procedure of calculating the characteristic value (C90) is defined in STN 75 7220 [114]. In each group, it determines the resulting water quality classes according to worst-case indicator of water quality. Using the system limits are to be assigned according to their water quality up to 5 quality classes (Tab. 16).

Tab. 15

Groups of indicators [110]

Group	Group water quality indicators	Water quality parameters
A	oxygen regime	dissolved oxygen, BSK_5, $ChSK_{Mn}$, $ChSK_{Cr}$
B	basic physico-chemical parameters	pH, water temperature, dissolved solids or conductivity, chloride, sulphate
C	nutrients	ammonia nitrogen, total phosphorus
D	biological indicators	biosestone saprobic index, index saprobic benthos
E	microbiological indicators	coliform bacteria, thermotolerant coliform bacteria
F	micropollutants	mercury, cadmium, arsenic, lead, copper, non-polar extractable compounds
G	toxicity	Acute toxicity to aquatic organisms (crustaceans, algae), seed germination
H	radioactivity	gross alpha, gross beta

Tab. 16

Classes of surface water quality [2]

Water quality class	Verbal assessment of water quality	Color coding classes in map outputs	Suitability for use
I. Class	very clean water	light	usually suitable for universal use, water supply purposes, food industry, recreational use, breeding salmonids, it has great landscaping feature
II. Class	clean water	dark blue	usually suitable for most other uses, water supply purposes, fish farming, sports, a landscaping feature
III. Class	polluted water	green	is generally only suitable for water supply industry, conditionally usable for supply purposes in the absence of a source of better water quality (multi-stage necessity of modifying it), it has a small landscaping feature
IV. Class	heavily polluted	yellow	usually only suitable for limited purposes
V. Class	very heavily polluted water	red	usually, it is not suitable for any purpose

Important component of surface water protection is prevention, not to create new sources of pollution and to reduce to a minimum the accidental pollution of surface water quality.

6.5 Biochemical Processes Waters - Self-cleaning Biochemical Process

The essence of biochemical water treatment is an **activity of microorganisms**. The basic prerequisite for this activity is the presence of a **living community of microorganisms** (mainly bacteria) as well as **physical and chemical conditions in the environment** that can normally run life processes of the community. Under the physical and chemical relationship means the **non toxicity environment suitable temperature and favorable hydrogen ion concentration (pH).** Another condition for living organisms is the **presence of food**. The food in the present case consists of organic, biodegradable agents (such as sugars, fats, proteins, phenols and the like.), Which is required to be removed from the waste water. The same physical and chemical conditions in the environment of treated waste water at many developed practically the same community of microorganisms [109].

Decomposition (mineralization) of degradable organic substances can occur due to the presence of oxygen, two main march [109]:

- **aerobic way**,
- **anaerobic manner.**

Aerobic way - while maintaining excess air is performed aerobic march. Life processes of microorganisms as whole influence step by step on the oxidation process of organic compounds. According to the concentration of organic matter (food), and micro-organisms, of the rate of reaction and the life of the technical performance of the object is currently being developed a number of different methods for the aerobic treatment of waste water.

Anaerobic way - at low or no dissolved oxygen takes place anaerobic march. The nature of anaerobic microorganisms in this case is different from the aerobic processes. Community is in this case formed of lower organisms, primarily bacteria. Anaerobic processes are actually processes of decay.

Self-cleaning biochemical processes in watercourses (or tanks) represents a natural way of cleaning water. The term self-cleaning water includes a summary of the physical, chemical and bacteriological processes in standing and running waters.

From an environmental point of view, self-cleaning processes in watercourses (in the recipient) and water reservoirs perfect example of self-regulation aquatic ecosystem at its caught from equilibrium (homeostasis). The clarity and brevity, this complex process can be divided into several basic and simultaneous storylines [2]:

- **biochemical decomposition** - decomposition of organic matter by microorganisms. The destruction of microorganisms necessarily need oxygen (O_2) and produce CO_2.
- **photosynthesis** - algae and aquatic plants consume only light resulting CO_2 and produce O_2. Algae are propagated in early grazing - predatory food chain at the end of which is fish or other aquatic animals,

- **dissolution of oxygen -** the oxygen in the air dissolves in the water and replaced by O_2 consumed in biochemical decomposition. In the absence of O_2 would have stopped underlying segment of self-cleaning process - biological decomposition of pollutants. The amount of dissolved O_2 is mainly dependent on the surface, speed, flow and aeration of water (waterfalls and rapids). If water covers the surface ice or floating pollutants (fats, oils, oil, foam, etc.), dissolution of O_2 stops,
- **direct consumption** - organisms can directly consume the pollution of organic origin (e.g. Wastewater from the food industry),
- **by gravity** - some hazardous substances entrained and moved the day to day can settle and create sludge, which contains O_2 and therefore there begins anaerobic digestion,
- **chemical reactions** - in the water flow leads to interaction between pollutants and aquatic environment. There may be a variety of chemical reactions leading to equilibrium. E.g.: neutralization - mutual precipitation reaction, adsorption - the day flows (heavy metals); oxidation - easily oxidizable reagents and the like.

March with self-cleaning in the water flow after a pollution condition improves and returned after some time (after a few km stream) back to its original state, unless further pollution. Illustratively, the processes of self-cleaning water flows shown in Fig. 101.

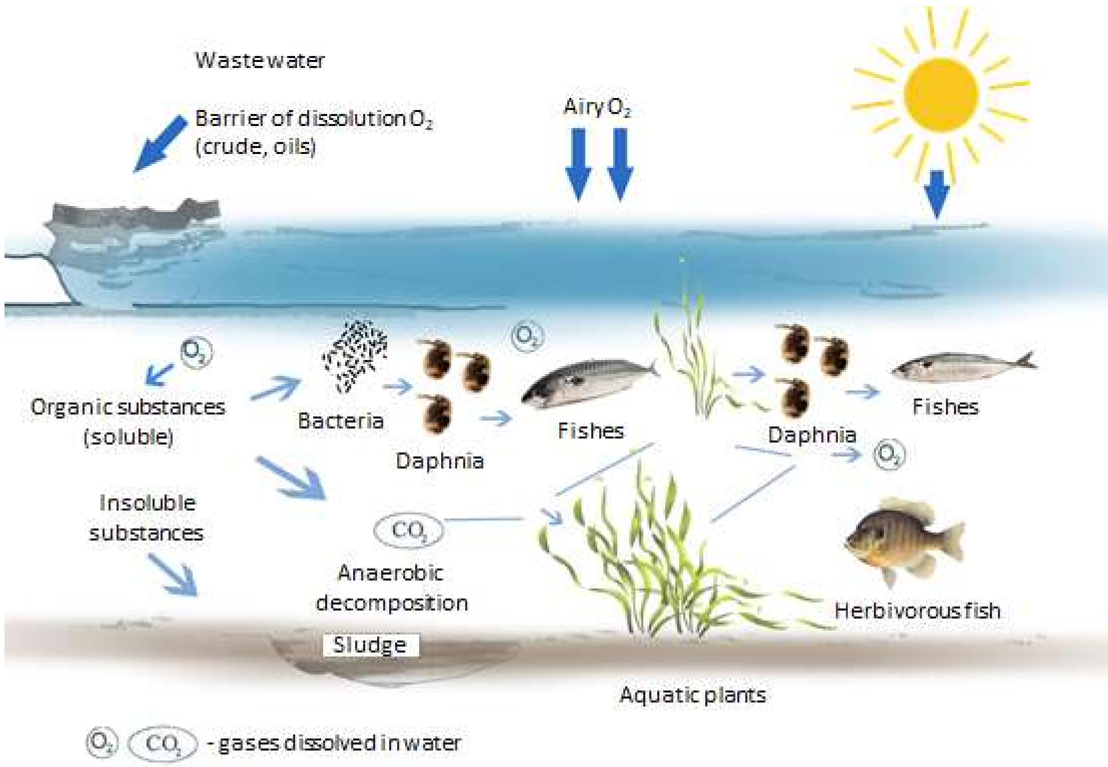


Fig. 101 Self-cleaning processes in watercourses [2]

6.6 Waste Water Treatment

In the world and in our country are first cleaned and controlled large point sources of pollution. Currently, the priority places emphasis on increasing the degree of removing pollution from the wastewater. Wastewater treatment can be divided as required to the level of wastewater treatment or by the basic methods (technologies). Pollution can be removed more technological processes, either separate or adjoining, thereby achieving the required quality of waste water discharged into receiving waters. Processes used in technology of wastewater should respect that:

- process must be efficient,
- the process must be economically acceptable,
- the process should not mix to waste water other pollutants.

Technological processes of purification and waste water treatment is principally divided into the following basic groups [2]:

- mechanical processes,
- physico - chemical and chemical processes,
- biological processes.

6.6.1 Mechanical Processes

For this process, the waste water treatment technologies mainly include [2]:

- **percolation and micro sieve,**
- **filtration,**
- **sedimentation.**

6.6.2 Physico-chemical and Chemical Processes

This group processes in waste water treatment technologies include [2]:

- **Flotation,**
- **Adsorption,**
- **Absorption,**
- **Clarification,**
- **Extraction,**
- **Ion exchange,**
- **Membrane separation processes,**
- **Reverse osmosis,**
- **Ultrafiltration,**
- **Electrodialysis,**
- **Electrochemical processes,**
- **Degassing,**
- **Radiation - chemical processes,**
- **Freeze,**
- **Crystallization,**
- **Emulsification,**
- **Magnetic separation,**

- **Stripping - striping,**
- **Immobilization,**
- **Disinfection,**
- **Neutralization,**
- **Shrinkage,**
- **Oxidation and reduction,**
- **Incineration.**

6.6.3 Biological Processes

Biological waste water treatment [116] includes a set of different processes, whose main feature is that the contained pollutants in waste water may serve the microorganism as a source of energy and material for cell synthesis. So the pollution changes the cells of microorganisms, which usually create settleable flakes or form increases the reactor charge and thus separated from the treated wastewater. These basic happening are performed by other phenomena, such as the coagulation and sorption of finely divided colloidal pollution of the flakes formed biomass, which are dependent on their composition slowly assimilated. The extensive modifications biological treatment processes freely bacteria, flakes of biomass becomes food other organisms, e.g. ciliated, worms and fish.

In this way the waste water to remove any substances, which can serve as a substrate of a microorganism (i.e., a source of energy and material for cell synthesis). Such materials are in particular most of the organic matter. By biologically method can be removed from waste water nitrogen, phosphorus and sulphate in a dissolved and undissolved form [116].

Biological wastewater treatment is self-cleaning ability of technical transformation recipient, ongoing help for aquatic organisms on an intensive process performed outside the natural water body in the reactors. The technical embodiment self-cleaning processes are concentrated into a small volume, guided and intensified by increasing the concentration of functional polyculture (biomass, activated sludge, biofilm), sufficient to cover increased demands for oxygen consumption by ensuring sufficient contact between biomass, oxygen and waste water and ensuring removal of inhibitors and the toxicant from the environment.
The biological treatment is substantially mimic the processes occurring in nature [116]. Microorganisms, especially bacteria cause a number of biochemical and chemical changes and are used in the sludge to break down, respectively. Elimination of unwanted substances from the waste water (organic pollution, nitrogen compounds, sulphur, phosphorus, etc.) and by controlling the supply of oxygen can be distinguished by a number of respects. According relation to oxygen is [116]:

- **aerobic**, they require molecular oxygen,
- **anaerobic,** living only in the absence of molecular oxygen,
- **facultative anaerobes,** capable of growing in the presence of oxygen without it.

In terms of metabolism of microorganisms are divided into:

- **Autotrophic -** nutritionists do not need organic matter, but use inorganic substances. Carbon assimilated in the form of carbon dioxide. CO_2 assimilation to use light energy (photosynthesis) or chemical energy (chemosynthesis), which usually acquire oxidation of inorganic sulphur compounds, nitrogen, iron and other elements. Photosynthetic assimilation CO_2 made green plants, algae, cyanobacteria and some bacteria, but some bacteria chemosynthesis.

- **Heterotrophic** - require for your life necessarily organic carbon source.

The lowest form of life that is seen in wastewater is viruses, bacteria, protists (protozoa), rotifers, worms and (multi-link). They are adapted to life in the aquatic environment. They are aquatic microorganisms. Source of nourishment for them are organic forms of pollution, which we refer to as the substrate. The environment, in which they live can be divided into [116]:

- **Aerobic (oxical) -** in the presence of molecular oxygen and the predominant forms are: NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{3-},
- **Anaerobic** - without oxygen,
- **Anoxic** - switch between them without molecular oxygen, immediately consume oxygen from oxidized forms, for example nitrite, nitrate, and the predominant forms are then NH_4^+, H_2S, S_2^-, P a S.

Strictly aerobic organisms will die without oxygen, strictly anaerobic perish in the presence of oxygen, facultative organisms - anoxic last for some time without oxygen. **Processes in wastewater treatment accordingly can be divided into aerobic, anoxic and anaerobic.**

The naturally organic matters are mineralized in the aerobic and anaerobic conditions. The difference between the two types of processes is not only in organisms that are carried out, but also in products. While under aerobic conditions the end products of CO_2, H_2O, NO_3^- etc., that is, by total digestion, always under anaerobic conditions results in metabolites (e.g. organic acids, methane), which are not further degrade.

Aerobic systems for biological wastewater treatment

Aerobic processes are based on the removal of organic materials by microorganisms in the presence of oxygen. Mutual role to play physical - chemical processes (coagulation, adsorption, and sedimentation). Micro-organisms decompose organic matter, releasing energy in the form and biomass. Part of the organic matter is oxidized to CO_2 and water, and the residue was converted to the stock material and to form new cells of biogas (methane and carbon dioxide).

When an aerobic biological treatment is used, functional polyculture is formed by a mixture of aerobic and anaerobic bacteria, molds, fungi, yeasts, protozoa, rotifers and worms. Suitable composition of polyculture is the composition of the wastewater and technological processes cleaning. The microorganisms utilize the organic compounds in the waste water as the substrate which partially oxidized to CO_2 and water, and also partly converted to new biomass.

Aerobic biological treatment is done [116]:

- in the activation tank,
- in biological columns.

Anaerobic systems for biological wastewater treatment

The main **anaerobic processes** that apply to certain cleaning and disposal of sewage sludge are **acidic** and **methane fermentation,** respectively **methanisation**.

Facilities for anaerobic waste water treatment are [116]:

- anaerobic reactors,
- anaerobic column.

Anaerobic processes are up to 95 % contamination transformed into biogas, which comprises: 60-80 % CH_4, 19 - 39 % CO_2, 1 % H_2O + H_2S + O_2 + NH_3, etc. The disadvantage is the anaerobic processes that subsequently the two must be connected oxical process.

6.7 Protection of Water Ratio and Water Resources in Slovakia

Surface and underground waters are one of the sources, form an important component of the natural environment and are used to provide economic and other societal needs.

Water protection is a basic water management activities aiming to protect water from pollution, exhaustion or other deterioration. Reasons for water protection are not only engineering, but also economic, social, health and environmental.

For these reasons legislative regulations in the field of water policy requires every person, who carries out any activity, which may affect the status of surface water bodies and groundwater, aquatic ecosystems and directly dependent from the water landscape ecosystems, the obligation to make efforts for their preservation and protection.

User of agricultural or forestry land is obliged to farm them in a way that preserves the right conditions for the presence of water and helping to improve water conditions. In particular, it is required to prevent harmful changes in drainage conditions of water, soil and burning of care to maintain soil water and improve the ability of the territory.

To protect significant areas providing water sources are in the law on water protection (Slovak Act No. 364/2004) promulgated:

- **The protected area of natural accumulation of water,**
- **Protection zones of water sources,**
- **Sensitive areas,**
- **Vulnerable areas.**

6.8 Knowledge and Information on Eutrophicated Eater Revitalization

Cyanobacteria and algae are predominantly photoautotrophic organisms that share a common way of life and obtain energy through photosynthesis. They are the primary organisms utilizing biogenic elements, mainly phosphorus and nitrogen. Collectively, they may be referred to as phytoplankton or phytobenthos, or they may form of various growths on objects in the aquatic environment. They are part of every aquatic ecosystem. The ideal environment for the development of cyanobacteria and algae is area eutrophic to hypertrophic.

In many cases, it is in the eutrophication of the environment that cyanobacteria and algae overgrowth occurs, which in many cases can cause problems. In most cases, there is an oxygen fluctuation between day and night, where the oxygen content in the water is high in the afternoon and, conversely, in the morning there can be a deficit that can cause mass mortality of aquatic animals, including fish.

This is why the question of how to control cyanobacteria and algae to create a balanced environment, in which these problems are not so pronounced, is increasingly being addressed.

6.8.1 Eutrophication

Standing waters with elevated nutrient content are a suitable environment for the onset of eutrophication processes during warm days (Fig. 102). The ability of water to provide the necessary living conditions can be collectively referred to as nutrient capacity, or trophic capacity. It depends primarily on the mineral content, temperature and light conditions necessary for biological production. Since water temperature and light conditions are determined by climatic conditions, which are difficult to influence, a change in the trophic content of the waters implies a change in the available nutrient content [110].

Eutrophication is a set of natural and man-made processes that lead to an increase in the concentration of biogenic elements (nitrogen, phosphorus) in waters and soils.

Natural eutrophication is caused by the release of nitrogen and phosphorus from soil, sediment and dead aquatic organisms.

Artificial eutrophication is caused by intensive agricultural production, increased production of industrial and municipal wastewater, the use of polyphosphates in detergents and cleaning products. [117]

Fig. 102 Eutrophication of waters [117]

External nutrient inputs to a water body can originate from point sources, which are located in a single location and much easier to monitor and control, and nonpoint sources, which are dispersed and much more challenging to monitor and control (Tab. 17). The relative proportions of each source vary among watersheds, depending on population density and land use.

Tab. 17

Point and non-point sources of pollution [106]

Point sources	Non-point sources
Wastewater (municipal and industrial)	Agriculture (including irrigation)
Landfills	Pastures
Livestock production	Places without sewerage and areas with sewerage and populations > 100 000 population
Mining and drilling activities, industrial sites without Sewage	Filtrates from settling tanks, leakages from septic tanks systems
Sewage outfalls (storm water) at towns with a population > 100 000 inhabitants	Construction sites with an area < 2 ha
Overflow in combined sewers (stormwater and wastewater)	Abandoned mines
Construction sites > 2 ha	Atmospheric deposition over water surfaces
	Activities in the landscape that generate pollutants (logging, draining swamps, building roads and water channels)

Nitrogen comes mainly from various organic wastes and fertilisers from agricultural activities. It is usually less critical than phosphorus in the eutrophication process. Like phosphorus and other nutrients, the nitrogen present in the form of dissolved substances is primarily taken up from the water by micro-organisms and plants. **Phosphorus** is also a vital component of the cellular structures of all living organisms and is essential for energy processes and protein synthesis. Nitrogen, like phosphorus, is an important component of cells, where it is involved in the synthesis of amino acids and proteins.

6.8.1.1. Causes of Eutrophication

In addition to carbon, oxygen and hydrogen, which plants get directly from water and atmospheric carbon dioxide, two essential nutrients are needed for their development: nitrogen and phosphorus. The third essential ingredient is silicon, which is essential for the development of diatoms.

During eutrophication, the concentration of nutrients in the water changes. In some cases, one of the three nutrients may be bound in aquatic organisms and unavailable for further algal growth - a so-called *limiting factor* according to Liebig's law of minimum.

The ratio of nitrogen and phosphorus compounds in the water determines which of these will be the limiting factor and therefore which of these must be controlled to prevent excessive algal and cyanobacterial growth. For optimum growth of organisms, the ratio of nitrogen to phosphorus is approximately 100 : 1. Most authors consider phosphorus to be the main limiting nutrient.

The waters of freshwater reservoirs can be classified into several groups according to their nutrient content: oligo-, meso-, eutro- and hypertrophic (Tab. 18).

Tab. 18
Classification of freshwater reservoir waters by trophic level

Trophy status	Description	TN[1] (mg.m^{-3})	TP[2] (mg.m^{-3})	chl *a*[3] (mg.m^{-3})	SD[4] (m)
Oligotrophic	Clean water with little organic matter or sediment and minimal biological activity.	< 350	< 10	< 3,5	> 4
Mesotrophic	Waters with more nutrients and higher biological productivity.	350 - 650	10 - 30	3,5 - 9	2 - 4
Eutrophic	Waters extremely rich in nutrients, with high biological productivity. Some biological species can be suppressed.	650 - 1250	30 - 100	9 - 25	1 - 2
Hypertrophic	Muddy, highly productive waters, approaching swamp status. Many biological species, living in clean waters, do not survive.	> 1200	> 100	> 25	< 1

1) total nitrogen
2) total phosphorus
3) chlorophyll and
4) transparency of the Secchi disk - is a measure of water quality, it is a quick, simple and accurate method for determining water quality.

6.8.1.2. Consequences of Eutrophication

A serious consequence of eutrophication is the periodic mass development of cyano-bacterial blooms or vegetative discolouration of the water. As a consequence of the increased input of the elements nitrogen and phosphorus into the reservoir, changes occur in the composition of the phytoplankton.

6.8.1.3. Negative Impacts of Massive Water Bloom Development on the Ecosystem

Cyanobacteria forming water flowers have a negative impact on the aquatic ecosystem. When they overpopulate, they collect on the surface and form a continuous layer that prevents the world from penetrating into the lower parts of the water column. This barrier results in the death of organisms that depend on light conditions [118].

Cyanobacteria have many competitive advantages over other organisms and so are able to destroy some of the less resilient communities and create a monoculture when they develop massively [118].

Another negative consequence of the massive development of aquatic blooms (Fig. 103) of cyanobacteria is a change in the oxygen regime in the reservoir. During the day, oxygen supersaturation conditions are created at the surface due to photosynthetic activity and the pH increases. At night and in the morning, oxygen is consumed by large quantities of cyanobacteria and anoxic conditions are created in the aquatic environment, causing the death of other organisms (e.g. fish that suffocate). Also in autumn, dissolved oxygen is depleted by bacteria decomposing organic matter that has sunk to the bottom of the tank after the cyanobacteria have died [119].

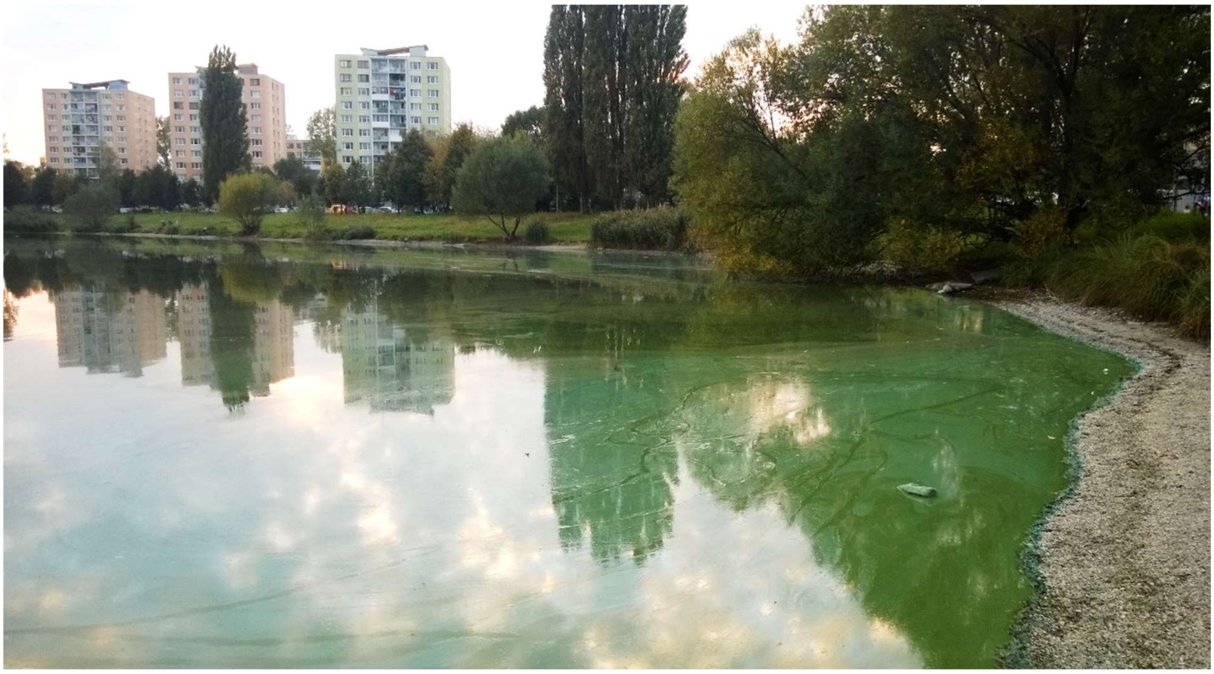


Fig. 103 Mass development of water flower on the water surface of the lake - municipal district and Jazerom, Košice, Slovakia

Some species of cyanobacteria release toxic substances - cyanotoxins - into the environment. In addition to causing damage or even death to some aquatic organisms, cyanotoxins pose a health risk to humans when they eat fish from aquatic wildflower ponds and when they eat vegetables irrigated with cyanobacteria-laden water [119].

6.8.1.4. Monitoring Eutrophication

The main reason for monitoring eutrophication is [110]:

- prevention of eutrophication,
- early warning of the population - public health authorities need information on the potential threat of eutrophication to be able to intervene in time,
- need to know the degree of eutrophication - water treatment plants need to have accurate information on water quality,
- Research.

Currently, few national water quality monitoring programmes include parameters indicating eutrophication. In Europe, the USA, Japan and Australia, local monitoring programmes to detect the presence of toxic algal and cyanobacterial species are gradually being implemented in areas where shellfish or fish are consumed. The programmes are based on water sampling from predetermined sites and on phytoplankton and shellfish analysis. The frequency of sampling depends on the season. These systems are focused only on monitoring toxic aquatic blooms that result from eutrophication [110].

Satellite imagery is now also used to monitor large bodies of water, which can monitor the presence and extent of high concentrations of ***chlorophyll a***, which informs about the presence of phytoplankton biomass in the upper layers of the eutrophicated area [110].

Data such as ***"growth of the number of macrophytes at the bottom of the water body expressed in g/m^2"*** or ***"mg chlorophyll a/l"*** are not, according to the definition of eutrophication, appropriate indicators for setting thresholds above which eutrophication is indicated. In fact, such indicators do not exist. To define the extent of eutrophication, data on the reference state of the system under assessment and its current or future state are needed. Since data on the baseline condition are not usually available, assessing eutrophication on a case-by-case basis is highly complex and difficult. The first sign of an advancing eutrophication process is a decrease in the oxygen concentration in the lower layers of the water body of standing waters and an increase in pH due to photosynthesis (CO_2 depletion). These parameters, complemented by direct microscopic observation, could predict the likelihood of the eutrophication process starting [110].

6.8.1.5. Measures to Reduce Phosphorus and Nitrogen

Reduction of nutrient and organic pollution can be achieved by measures to address point sources of pollution and to reduce area-based pollution. Progressive measures are needed to improve the status of water bodies:

- in agglomerations,
- construction, extension and reconstruction of public sewers,
- construction of new wastewater treatment plants and intensification of existing wastewater treatment plants,
- construction and reconstruction of sludge management,
- stormwater treatment - building stormwater basins,
- construction of wastewater treatment plants in industrial and agricultural enterprises,
- legislative provision for the production of phosphate-free laundry detergents.

6.9 Knowledge and Information on Eutrophicated Eater Revitalization

Cyanobacteria (Fig. 104) are a group of bacteria capable of producing oxygen through photosynthesis like plants. They are gram-negative, simple, prokaryotic, phototrophic micro-organisms. They occur as single cells, filamentous or in colonies. The size of individual cyanobacterial cells varies from 1 to 10 µm. Cyanobacteria live in fresh, marine and brackish waters [120].

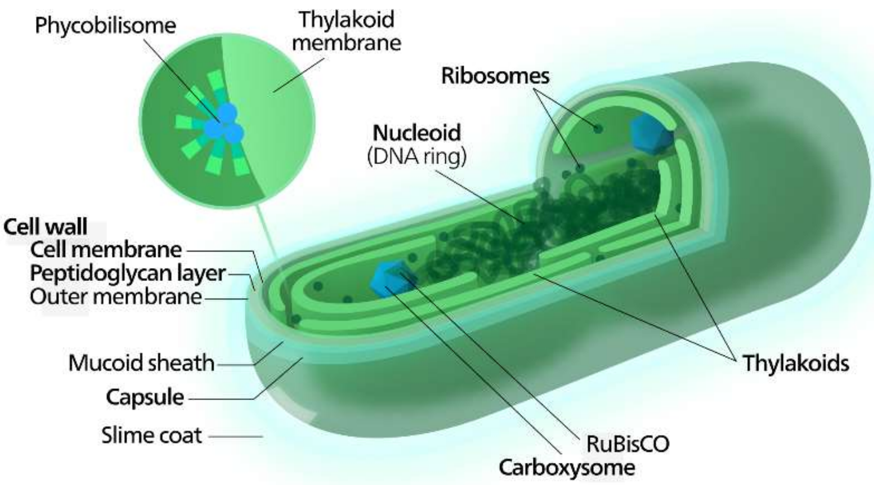


Fig. 104 Cross-section of a cyanobacterium [121]

The body of a cyanobacterium is most often blue-green in colour, containing a circular DNA molecule, simple membrane structures and bacterial-type ribosomes. Photosynthetic dyes are stored loosely in the protoplast in special formations - thylakoids. Complementary (accessory) pigments (phycobilins) are stored in small spherical bodies in phycobilisomes (Fig. 105) [120].

Reproduction in unicellular and colonial cyanobacteria is by cell division and in filamentous cyanobacteria by akinetes. They are able to survive in the most hostile environments such as Antarctica, hot baths, clean mountain environments and contaminated sewage [120].

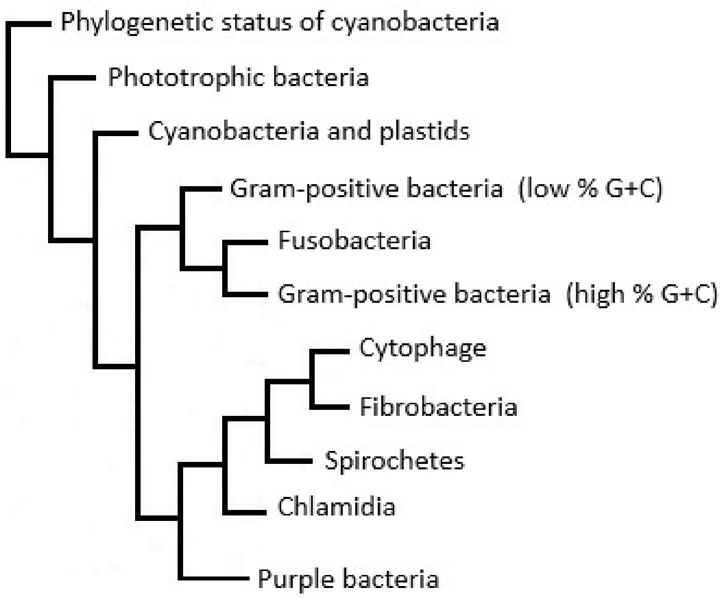


Fig. 105 Phylogenetic position of cyanobacteria (adapted from Graham and Wilcox) [120]

6.9.1 Terminology, Basic Concepts

The term cyanobacteria is a common Slovak-Czech name. The name cyanobacteria comes from the term "**blue**" = blue is basically a translation of the "**Latin**" name, from the Greek **cyanos** = blue. [122] Sometimes cyanobacteria are incorrectly referred to as blue-green algae. In recent years, the name cyanobacteria or cyanoprokaryotes has been very commonly used.

These designations are terminologically correct and in accordance with the International Bacteriological Code. A third appropriate term in accordance with the International Code of Botanical Nomenclature (**ICBN)** is *cyanophyta*. The name cyanophyte is neutral with respect to both codes.

Basic concepts [123]**:**

Autotrophy - is way of feeding green plants and some bacteria, taking carbon from carbon dioxide and getting energy from light or oxidation of inorganic substances.

Endoplasmic reticulum - is a set of membrane formations in the cytoplasm.

Phytobenthos - are tiny microscopic plants that live on the bottom of surface waters.

Phytoplankton - are plant organisms on the surface of the water, plant plankton.

Golgi apparatus - is a set of membrane formations, mainly used for the formation of secretions.

Chitosan - is a natural animal fiber obtained from the shells of marine crustaceans with high binding capacity.

Ichthyofauna - certain species of fish in a particular area.

Macrophytes - are vascular plants with leaves floating on the surface.

Plankton - is a community of tiny organisms moving passively in water.

Plastids - are organelles of green plant cells in which photosynthesis takes place.

Algae - collective name for the oldest microscopic plants capable of photosynthesis, probably phylogenetic descendants of cyanobacteria, which also have this ability.

Cyanobacteria - prokaryotic microorganisms with oxygenic photosynthesis.

Cyanobacterial water bloom - a mass occurrence of planktonic cyanobacteria visible to the aquatic eye in the form of tiny macroscopic spheres.

Thylakoids - are lamellar membrane structures that form grana in the chloroplast stroma or are localized singly.

Aquatic ecosystem - is a dynamic unit of communities of aquatic organisms and abiotic, water- bound environment.

Aquatic bloom - mass occurrence of planktonic cyanobacteria and algae in eutrophic waters causing the water to turn yellow-green, dark brown to dirty red.

Zooplankton - is a community of animals floating on the water surface, animal plankton.

6.9.2 Evolution of Cyanobacteria

In terms of evolution, these are the oldest and most primitive forms of life on Earth, which appeared on our planet in the Precambrian 3,5 billion years ago. They became the dominant group of organisms 2 billion years ago [124]. According to the fossils found, they probably played a very important role in shaping the Earth's oxygenated atmosphere (Fig. 106). Anaerobic photosynthesizing bacteria (chlorobacteria and purple bacteria) are thought to be their ancestors. [119]

Fig. 106 Evolution [124]

6.9.3 Ecology of Cyanobacteria

Cyanobacteria live in fresh, marine and brackish waters, and are also found in habitats with high humidity, in soil and in damp wood. They also inhabit extreme habitats such as hot thermal springs or layers of snow and ice. In still and flowing waters, cyanobacteria form an important component of the phytoplankton. Cyanobacteria are important primary producers and many other organisms depend on them. They can live in symbiosis with fungi or aquatic animals. When mass overgrowth occurs, they form an aquatic bloom. Some produce toxins. [124]

6.9.4 Construction of the Cell

The cell structure (Fig. 107) of cyanobacteria is very simple. Cyanobacteria do not have a nucleus, mitochondria, Golgi apparatus, endoplasmic reticulum, vacuoles or chloroplasts in their cells. The solid cell wall of cyanobacteria is four-layered, composed of the peptidoglycans murein and diaminopimelic acid (its composition does not allow protoplast staining). Therefore, we classify cyanobacteria as Gram-negative bacteria. The plasma membrane beneath the surface of the cell wall serves to actively transport ions and secrete substances and also initiates the separation of daughter protoplasts during cell division. [125]

A very striking formation inside the cyanobacterial cell are the thylakoids, where photosynthesis takes place. In the thylakoid are lipophile pigments, chlorophyl and main photosynthetic pigments beta-carotene, xanthophylls (echinenone, myxoxanthophyll, zeaxanthin). On the surface of the thylakoids are the so-called phycobilisomes, which contain the dyes: blue c-phycocyanin, red c-phycoerythrin, and blue allophycocyanin. The resulting colour of the cyanobacterial cell is determined by the ratio of red to blue pigment, which varies depending on the surrounding conditions. This is called chromatic adaptation. [125]

Cyanobacterial starch (-1,4 glucan) is the main storage substance. An intricately evolved circular DNA molecule, called a genophore, carries genetic information. The genophore of cyanobacteria lacks histoproteins. [125]

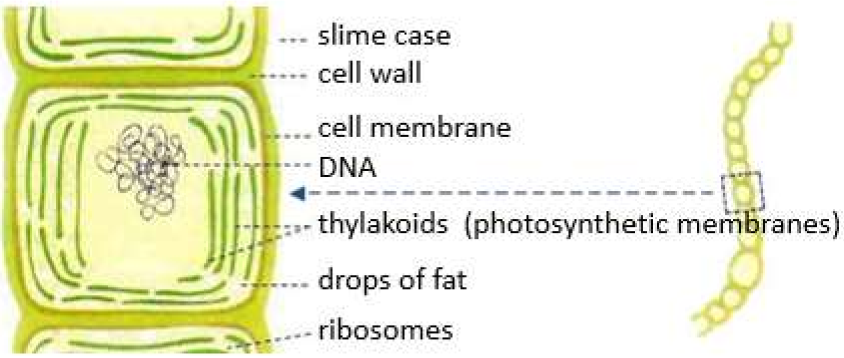


Fig. 107 Structure of the cell and its structure – modified [110]

6.9.5 Morphology and Cytology

Thus, cyanobacteria are prokaryotic autotrophic organisms with a unicellular or filamentous litter, which consists of self-vegetating prokaryotic cells undifferentiated into plexuses. Their cells are covered by a thick cell wall and enveloped by a mucilaginous layer.

The cytoplasm is microscopically distinguishable into two regions [110]:

- **chromatoplasm** - the outer part of the cytoplasm with colored photosynthetic structures,
- **centroplasm** - the central part of the cytoplasm containing genetic information and ribosomes.

The cells of cyanobacteria do not have the ability of active movement. At most, some can move by passive gliding motion caused by the production of mucus.

Photosynthetic structures of cyanobacteria are **thylakoids** containing assimilatory dyes. The photosynthetic dyes of cyanobacteria are **chlorophyll a**, which is the main. Other pigments are accessory, the most important being blue **phycocyanin** and red **phycoerythrin**. As a result of these accessory pigments, the cells are blue-green, brown-green, purple, pink, red, but never have the color of leaf green. Carotenoids are also always present.

Photosynthetic dyes are not incorporated into the chloroplasts, as is the case with eukaryotic photosynthetic dyes, but are concentrated into the thylakoids of the chromatoplasm.

The specific cells of some filamentous cyanobacteria are aerotrophs, heterocysts and akinetes, differing from vegetative cells in shape and often in colour. **Aerotrophs** (Fig. 108) are tiny gas-filled structures; their number in the cell regulates buoyancy and hence position in the water column. This allows the cyanobacteria to stick below the surface, where there is plenty of light, or near the bottom, where in turn there is plenty of nutrients. In this way, the cyanobacteria can wander through the water column and choose the environment that suits them best at the moment. Another speciality is **heterocysts**, which are formed by the transformation of vegetative cells and have a strikingly thick cell wall. They have the ability to assimilate airborne nitrogen. **Akinetes** (Fig. 108) also arise from vegetative cells, in which the amount of storage substances is increased; of the pigments only carotenoids are retained. They can withstand extreme conditions [110].

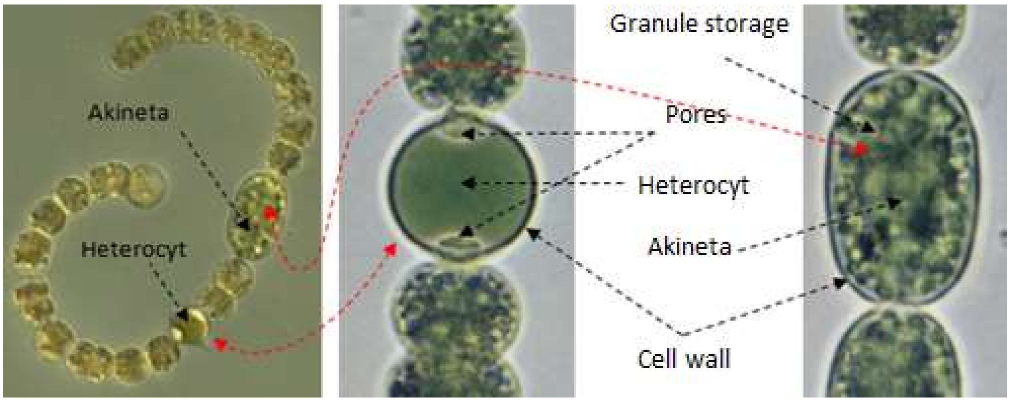


Fig. 108 Heterocysts and akinetes – modified [110]

False branching (Fig. 109) is a loose connection of fibers, most often by means of mucilage sheaths. True branching is produced by the separation of cells in a plane perpendicular to the original plane of division.

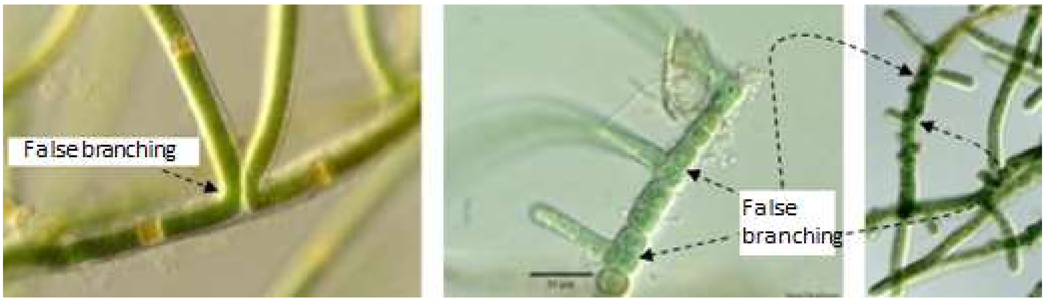


Fig. 109 True versus false branching [110]

The shape diversity of cyanobacteria varies. The shape of unicellular or colonial cyano-bacteria (Fig. 110) is oval, spherical, club-shaped, cylindrical and occasionally spindle-shaped.

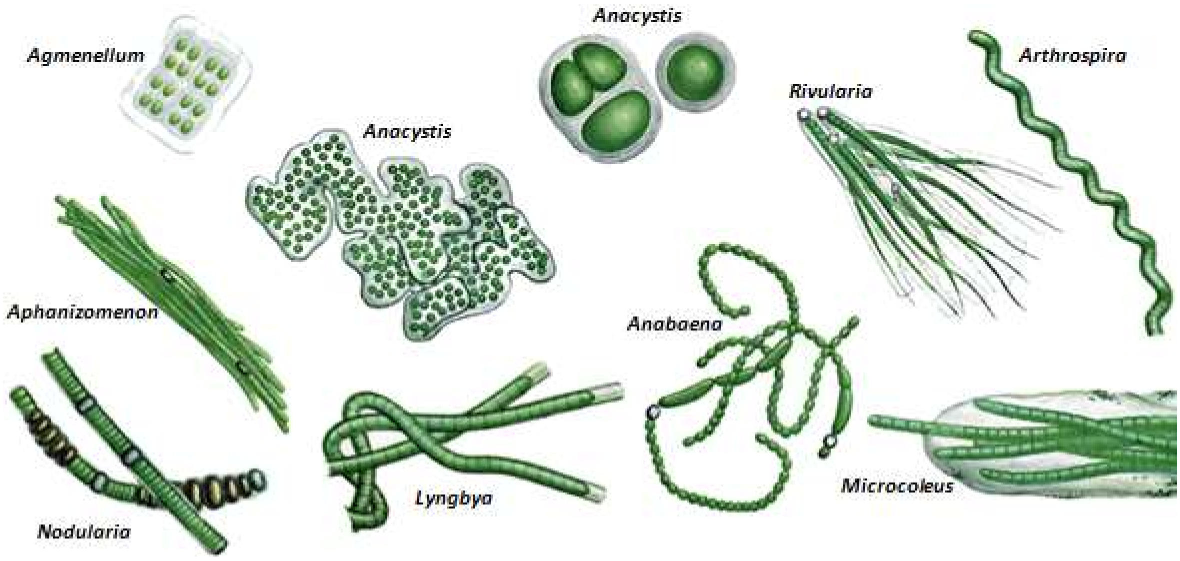


Fig. 110 Facial diversity of cyanobacteria [110]

6.9.6 Reproduction

Cyanobacteria reproduce asexually. Asexually, they can reproduce either by cell division into two parts or vegetatively, either by parts of the stalk, colonies, loose filaments or parts of filaments - called **hormogonia** (Fig. 111). The dividing cell grows from the edge to the centre similarly to the cells of plants. Sexual reproduction has not been observed in them. However, it is thought that genetic recombination may proceed as in bacteria by a "**parasexual process**".

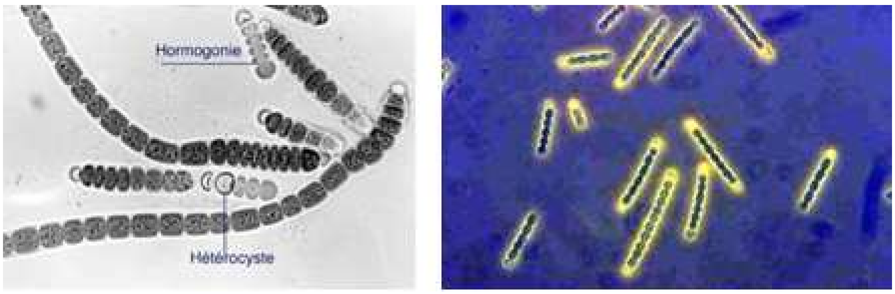
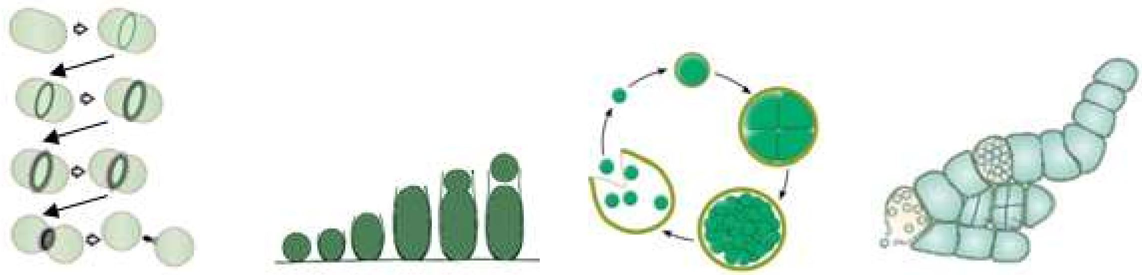


Fig. 111 Hormogonia [110]

The mucus sheath is not involved in the division. In the simple case, the cells divide into **two identical daughter cells** (*Synechococcus*) (Fig. 112 a)).

The division of some genera of cyanobacteria takes place **in two or three mutually perpendicular planes.** Colonies of some genera (*Merismopedia, Chameasiphon*) are also formed in this way. The genus *Chameasiphon* reproduces by exocytes (Fig. 112 b)) (exospores). **Exospores** are tiny, spherical and are released after rupture of the apical part of the cell wall. The genus *Chroococcidiopsis* reproduces by **beocytes** (Fig. 112 c)). They are tiny spherical cells formed after multiple divisions of the parent cell and are released after complete dissolution of the parent cell wall [110].



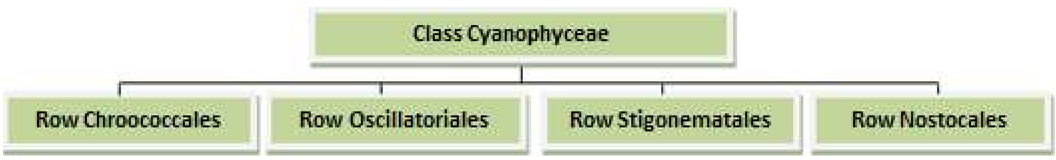
Simple division **(Synechococcus)** a) | Exocytes **(Chamaesiphon)** b) | Beocytes **(Chroococcidiopsis)** c) | Necrotic cells and hormogony **(Oscillatoria)** d)

Fig. 112 Cell division [110]

The growth of filaments proceeds by cell division similar to that of unicellular cyano-bacteria. In cyanobacteria of the genus *Oscillatoria* (Fig. 112 d)), cell division occurs near the end of the filament. Here we can also find cells with incomplete cell compartments. That is, a new division starts even before the previous one has finished. In some species (*Nostocales*) the filaments branch. There is also a false branching (*Tolypothrix*), it occurs by deflection of the filament from its original direction after overcoming an obstacle, for example a heterocyte or a necrotic cell. True branching is associated with a change in the plane of division of any cell. [110]

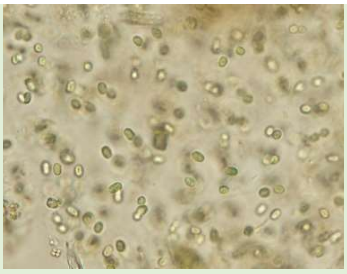
6.9.7 Systematic Breakdown

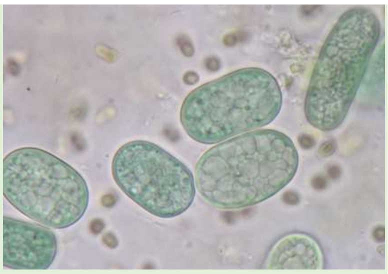
They used to be classified either as **lower plants** or as a separate unit on the same level with **bacteria**. Today they are classified as **gram-negative bacteria**. Both the plant code and the prokaryote code apply to their naming. At present, all cyanobacteria belong to one **class**, i.e. the class *Cyanophyceae* (division *Cyanobacteria/Cyanophyta*). There are at least a few genera 200 and several thousand species known. At present, cyanobacteria can be divided into four systematic orders [110]:

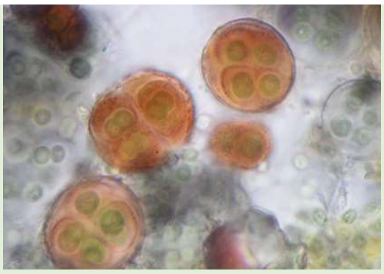


Order Chroococcales - simple coccal cells that can associate into colonies. They do not have acinettes or heterocytes, they divide by simple cell division.

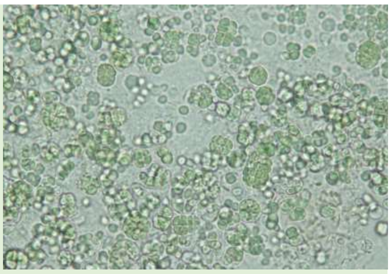
The best known genera include: *Aphanothece, Cyanothece, Gloeobacter, Gloeocapsa, Chamaesiphon, Chroococcidiopsis, Merismopedia, Microcystis, Synechococcus, Woronichinia (Fig. 113)*.

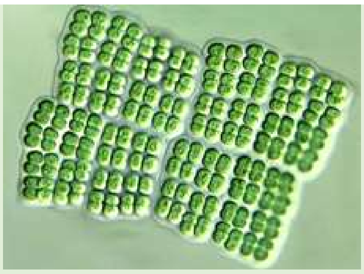

Genus Aphanothece

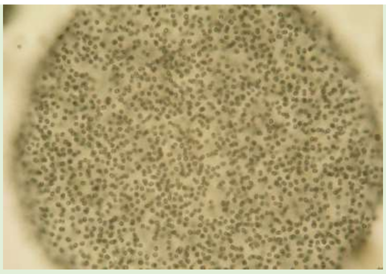

Genus Cyanothece


Genus Gloeocapsa


Genus Chamaesiphon


Genus Chroococcidiopsis


Genus Merismopedia


Genus Microcystis


Genus Synechococcus

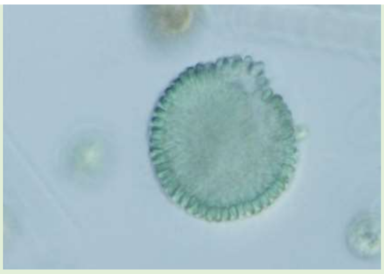
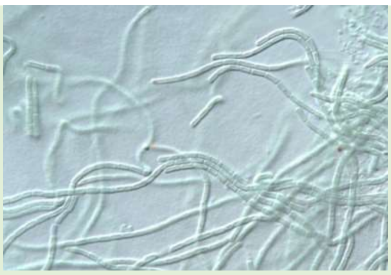

Genus Woronichinia

Fig. 113 Cyanobacteria of the order Chroococcales [110]

***Order Oscillatoriales* -** (dredges) - simple cyanobacteria with a filamentous (trichal) stalk. They have neither acinetes nor heterocytes, but may have aerotrophs. They reproduce by hormogonia.

The best known genera include: *Arthrospira, Leptolyngbya, Limnothrix, Lyngbya, Oscillatoria, Phormidium, Planktothrix, Spirulina (Fig. 114).*


Genus Arthrospira


Genus Leptolyngbya


Genus Limnothrix

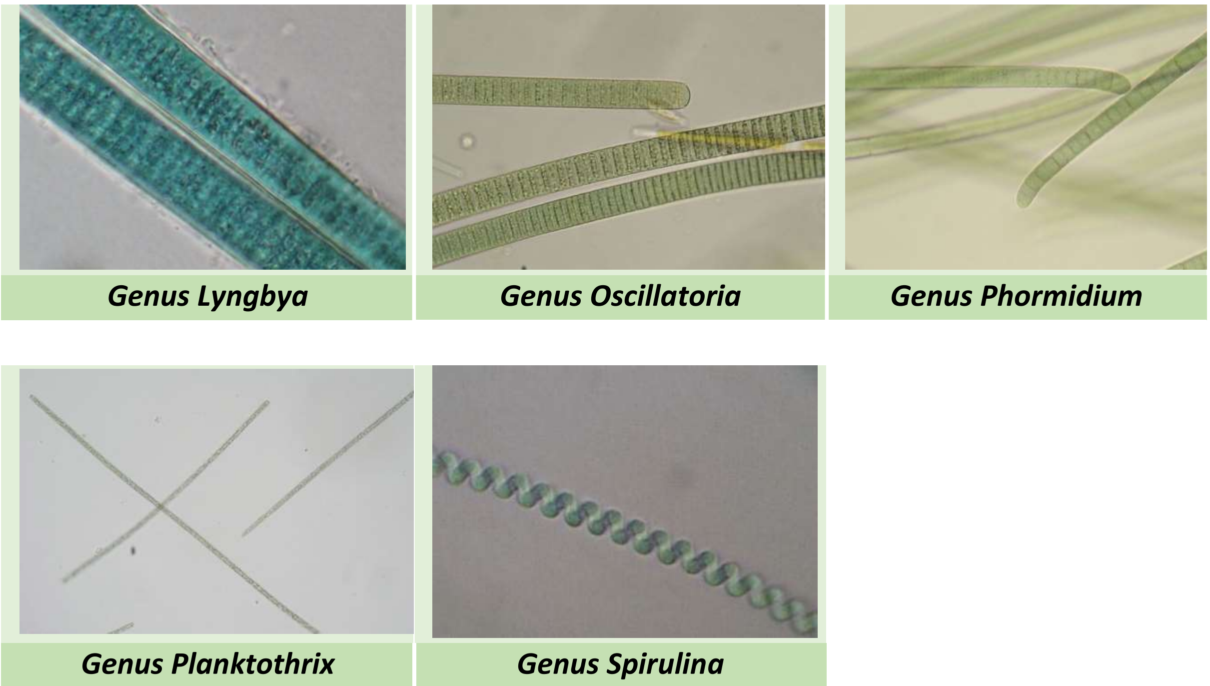
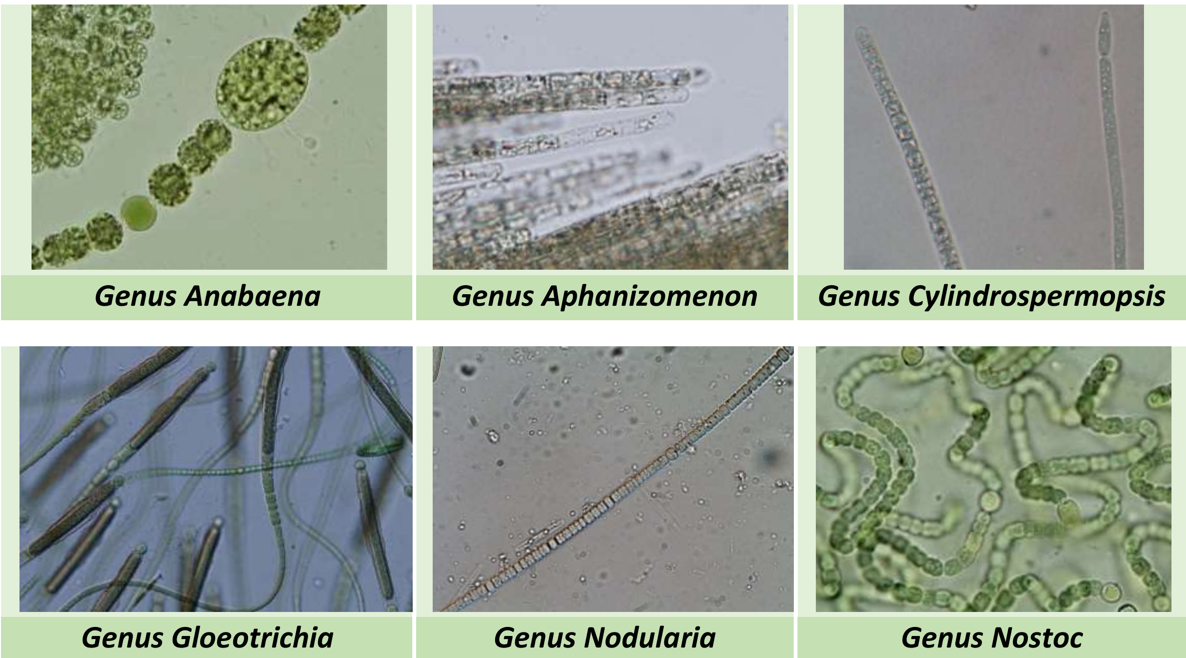


Fig. 114 Cyanobacteria of the order Oscillatoriales [110]

Order Nostocales – their body is formed by a trichal thallus, which is chain-like or not right branched. They have akinetes, heterocytes and often also aerotopes.

The best known genera include: *Anabaena, Aphanizomenon, Cylindrospermopsis, Gloeotrichia, Nodularia, Nostoc, Scytonema, Trichormus (Fig. 115).*

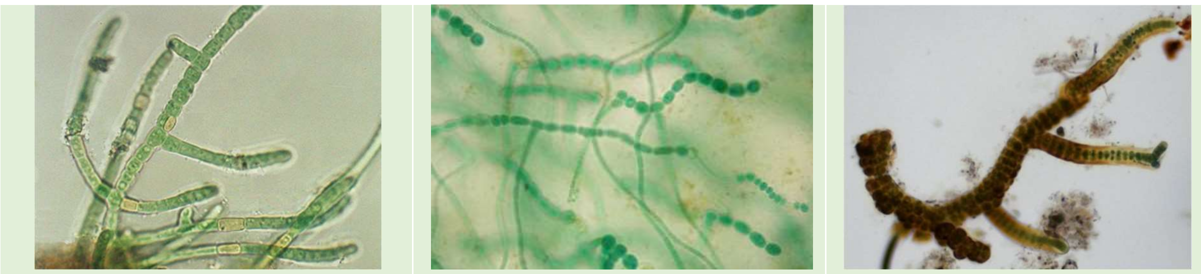


Genus Scytonema | ***Genus Trichormus***

Fig. 115 Cyanobacteria of the order Nostocales [110]

***Order Stigonematales* -** trichal stem, right branching, have heterocytes, no aerotrophs, akinetes, live in fairly extreme conditions, e.g. hot springs.

The best known genera include: *Geitleria, Hapalosiphon, Mastigocladus, Stigonema (Fig. 116).*



Genus Hapalosiphon | ***Genus Mastigocladus*** | ***Genus Stigonema***

Fig. 116 Cyanobacteria of the order Stigonematales [110]

6.9.8 Substances Produced by Cyanobacteria

Cyanobacteria produce and subsequently release a wide variety of chemically unique secondary metabolites, called cyanotoxins, into their surroundings. Most of these are highly toxic or otherwise biologically active. They can be very dangerous to humans and other organisms. It is not yet known exactly why cyanobacteria produce these toxins. It is thought that they have a protective function. Cyanobacterial toxins are very stable substances and cannot be removed from water by conventional water treatment processes such as flocculation, sedimentation, sand filtration, chlorination or simple boiling etc... It is very difficult to achieve the hygiene limits allowed for drinking water in surface water treatment, e.g. 1 mg/l for microcystin-LR according to. [126]

6.9.8.1. Cyanotoxins

Cyanotoxins are not actively excreted into the environment, they are washed out of the cells only after their decay. The production of toxins is only in some species of cyanobacteria, in freshwater one third of the approximately 50 genera. Toxin production varies from genus to genus, even within species. Cyanotoxins are diverse both chemically and toxicologically. Chemically, they are peptides, alkaloids and lipopolysaccharides (Tab. 19). Their main toxic effects are hepatotoxic (on the liver), neurotoxic and dermatotoxic (on the skin); effects on immunity, embryos and tumour-promoting have been identified. Toxin production is directly proportional to growth rate. Changes in light exposure induce two- to threefold differences in toxin production. Cyanotoxin production is maximal at 18 – 25 °C and depends on nitrogen and phosphorus concentrations [120].

Cyanotoxins are classified into three main groups based on their site of action [120]:

- **hepatotoxins**:
  - microcystins,
  - nodularins,
  - cylindrospermopsin,
- **neurotoxins**:
  - anatoxin-a,
  - anatoxin-a(s),
  - saxitoxin,
  - neosaxitoxin,
- **dermatotoxins**:
  - lyngbyatoxin,
  - aplysiatoxin.

In addition to these types of effects, they are also attributed to genotoxic, immunotoxic and embryotoxic effects.

Tab. 19
Significant groups of toxins produced by cyanobacteria [120]

Name of toxin	Structure	LD_{50}* ($\mu g.kg^{-1}$)	Toxicity	Mechanism effect	Main producers
Anatoxin	Alkaloids	200 - 250	Neurotoxicity	Agonists in nicotinic acetylcholine receptors	*The genera Anabaena, Oscillatoria Aphanizomenon, Microcystis*
Anatoxin-a(S)	N-hydroxy- guanine methyl phosphoester	20	Neurotoxicity	Inhibition of acetylcholin e- -esterase	*The Anabaena family*
Aplysiatoxin			Dermatotoxicity, support tumors	Activation of protein kinase C	*Lyngbya families, Oscillatoria*
Cylindrospermopsin	Guanidine alkaloid	200	Cytotoxicity, most affected. liver and kidneys	Inhibition of proteosynthes is and glutathione synthesis	*Species of Cylindrospermopsis raciborskii, Umezakia natans, Aphanizomenon ovalisporium*
Lipopolysaccharides			Irritant effects		*Part of the cell wall all cyanobacteria*
Lyngbyatoxin	Modified cyclic dipeptide		Dermatotoxicity, tumour support	Activation protein kinase C	*Species Lyngbya majuscula*
Microcystin	Cyclic heptapeptides	50 - 1 200	Hepatotoxicity, tumor promotion, oxidant induction. stress, etc.	Inhibition of oteinphosph atases 1 and 2A	*The genera Anabaena, Microcystis, Oscillatoria, Nostoc, Nodularia, Anabaenopsis*
Nodularin	Cyclic pentapeptides	50 - 2 000	Hepatotoxicity, tumour promotion	Inhibition of protein phosphatases 1, 2A and 3	*Species Nodularia spumigena*
Saxitoxins	Carbamate alkaloids	10	Neurotoxicity	Blockage of sodium channels in axons of neurons	*Anabaena, Aphanizomenon, Lyngbya, Cylindrospermopsis*

Note: *Agonist chemical compound that interacts with a receptor to mediate the biological effect of a toxin on a cell.*

Hepatotoxins - we encounter them most often and they damage the liver. In mice, acute exposure within a few hours led to death due to hepatic haemorrhage or circulatory failure. Chronic exposure damages the liver and leads to tumour formation. Hepatotoxins (Fig. 117) are referred to as substances capable of inducing liver cancer. [123]

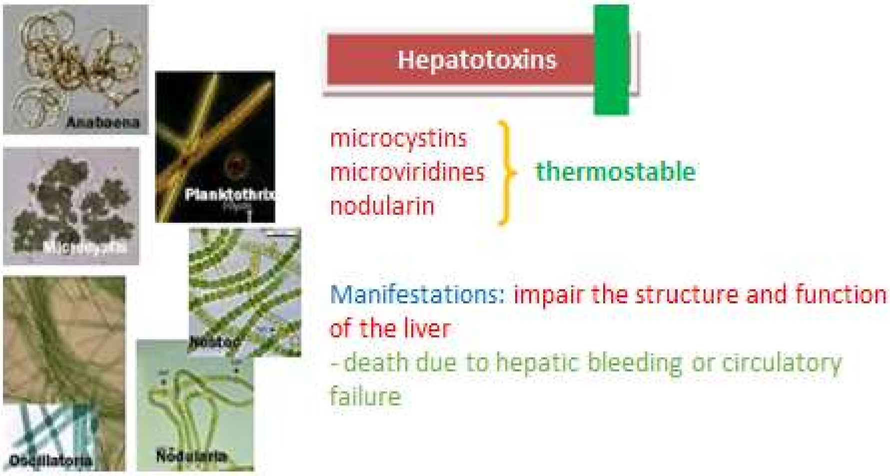


Fig. 117 Hepatotoxins – modified [123]

Hepatotoxins are thermostable and are produced mainly by the genera Anabaena, Microcystis, Oscillatoria, Nodularia, Nostoc and Planktothrix.

Neurotoxins - their occurrence is not as frequent as that of hepatotoxins (Fig. 118). They act primarily on the nervous system. After ingestion, they can lead to sudden death due to acute respiratory arrest due to nerve muscle paralysis within minutes after exposure. [123]

Unlike hepatotoxins, neurotoxins are thermolabile and their destruction occurs in alkaline environments at temperatures above 40 °C. The manifestations of neurotoxins are musculoskeletal convulsions, dizziness, asphyxiation and death by suffocation. Neurotoxins are produced by the genera *Anabaena, Microcystis and Planktothrix*. [123]

Fig. 118 Neurotoxins – modified [123]

Dermatotoxins - cause skin irritation or allergic reactions after contact - respiratory problems, conjunctivitis, etc. The target organs in cyanotoxin (Fig. 119) poisoning and the species of toxin-producing cyanobacteria are listed in (Tab. 19). [123]

Detection of cyanotoxins can be: biological, bacteriological, enzymatic, immunological, physicochemical. [123]

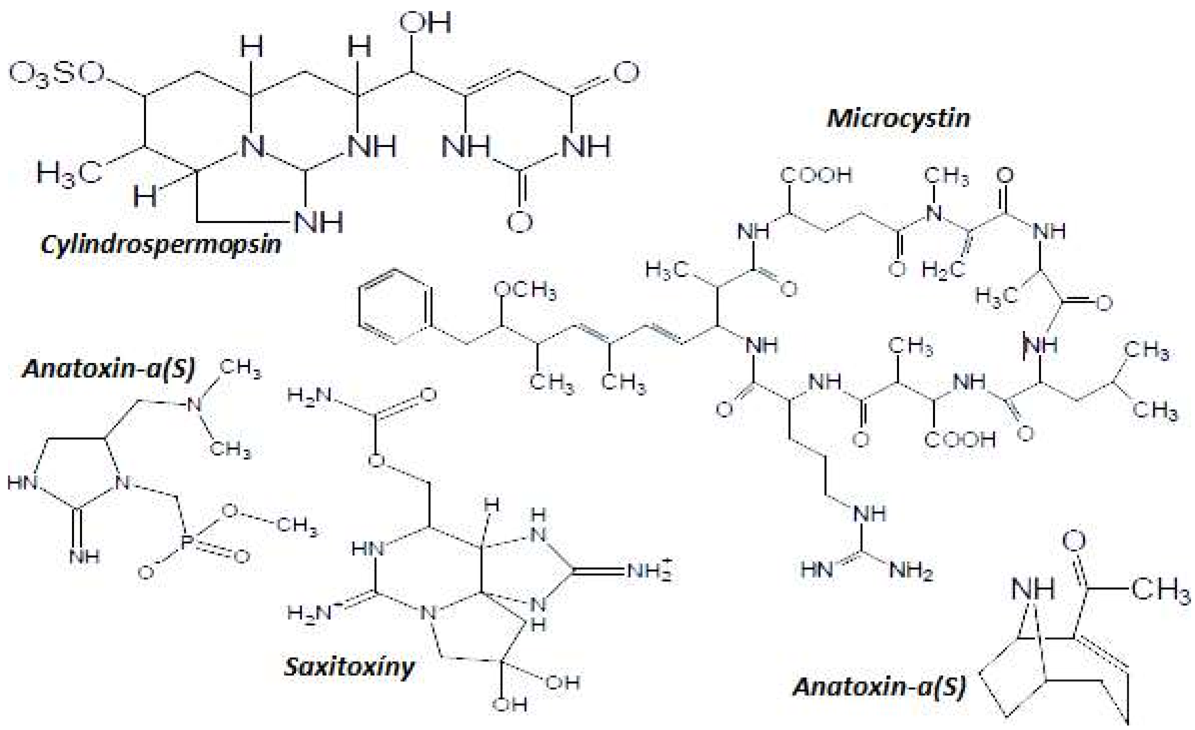


Fig. 119 The most important cyanotoxins [123]

The following Fig. 120 the toxin detection scheme.

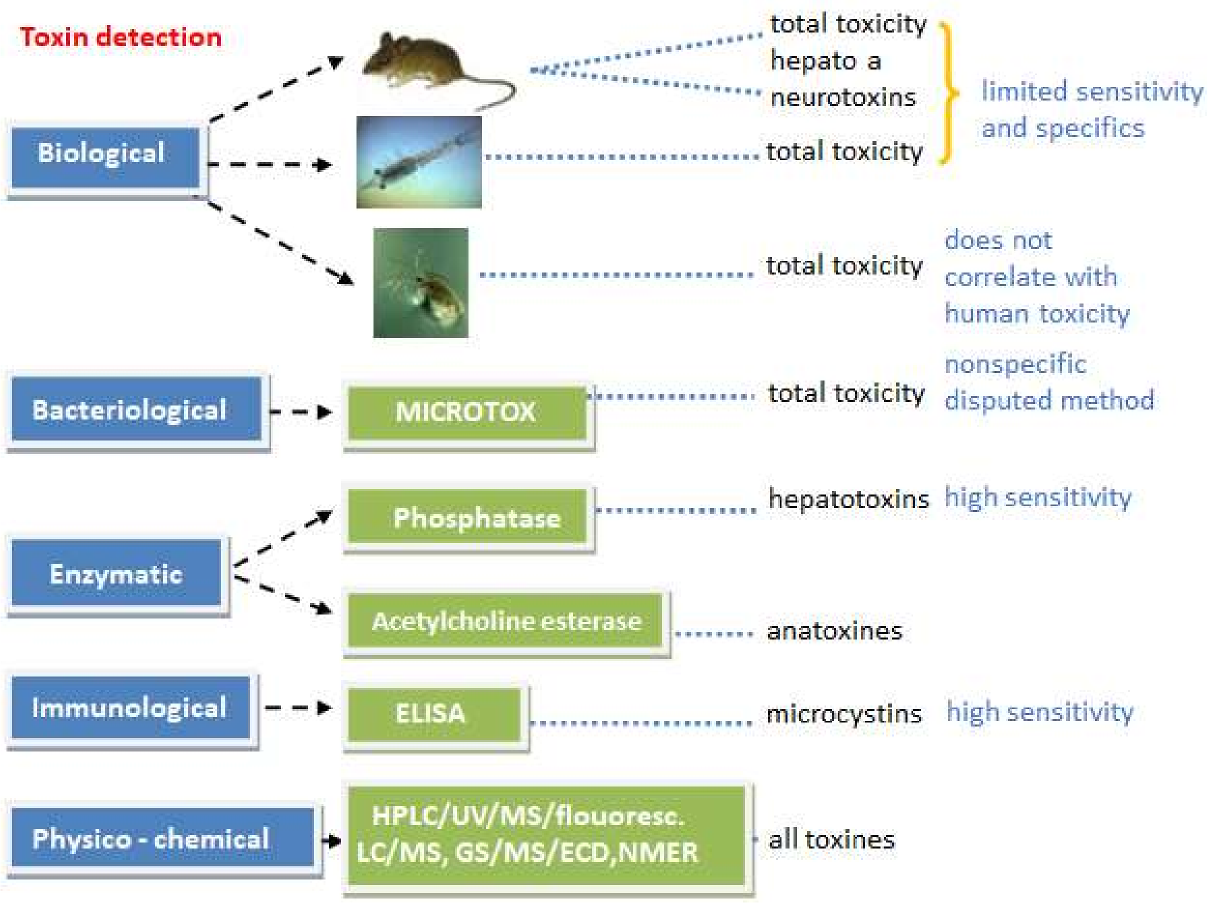


Fig. 120 Schematic of toxin detection - modified [123]

6.9.8.2. Health Problems Caused by Cyanobacteria

Cyanotoxins are substances that can affect other components of the ecosystem as well as the human body. Diseases due to cyanotoxins vary depending on the type of toxin, its content in the water and the type of contact (consumption, skin contact, etc.). People are affected by a range of symptoms including skin irritation, stomach cramps, vomiting, nausea, diarrhea, fever, sore throat, headache, muscle and joint pain, blistering in the mouth, liver damage, asthma. Swimmers bathing in waters contaminated with cyanotoxins are particularly affected by these problems. Animals, birds and fish can be poisoned by high doses of toxins produced by cyanobacteria [110].

However, not all cyanobacteria of **"dangerous**" genera produce toxins; on the other hand, there are undoubtedly as yet unrecognised cyanobacterial toxins.

Toxin-producing cyanobacteria are commonly present in the bathing waters of the Slovak Republic. In recent years, especially genera with proven toxicity have become invasive. Cylindrospermopsis, Aphanizomenon, Microcystis can also be observed in random samples of bathing waters around Košice.

6.9.8.3. Influence of chemical and physical factors on cyanobacterial development and cyanotoxin production

Most studies show that cyanobacteria generally produce toxins under conditions that are mosnt ginseueitrianbgle for their growth. Different species of cyanobacteria have different light requirements, e.g. *Planktothrix* prefers low light intensity, *Anabaena prefers* moderate light intensity and *Aphanizomenon* prefers high light intensity. The optimum growth temperature varies slightly from stem to stem. In the vast majority of studies, the highest toxin content was observed at temperatures between 18 °C and 25 °C, while low (10 °C) or very high temperatures (30 °C) reduced toxin production. Temperature gradients cause up to threefold differences in toxin content. [110]

When the effect of pH was studied, it was found that toxin production is higher when cyanobacteria is grown at high or low pH. The most important factor in terms of cyanobacterial growth is nutrient availability.

6.9.9 The Importance, Occurrence and Uses of Cyanobacteria in Nature and for Humans

Cyanobacteria are of great ecological and economic importance in rice paddies and other flooded soils (Fig. 121), where they enrich the soil with nitrogen.

Fig. 121 Fertilisation of rice paddies with cyanobacteria [123]

Cyanobacteria are also an integral part of many symbioses with other organisms. The best known is lichenism - this is the symbiosis of cyanobacteria with fungal hyphae in lichens (e.g. cyanobacteria of the genus Nostoc in lichens of the genus Colema). Cyanobacteria can also occur in the intercellular spaces or in the surface folds of the cells of some plants, such as liverworts, ferns and ferns. They also live on the surface or in the surface 15 scales of tropical plants (Bromeliads) as airborne nitrogen fixers. They can live with some aquatic animals (protozoa, marine sponges, urchins, molluscs). Overgrowth of cyanobacteria, e.g. species of the genera Microcystis, Anabaena and Planktothrix, in waters with an excess of nitrogen and phosphate nutrients results in aquatic blooms (Fig. 122). The water bloom consists of aquatic algae, which are harmless except to allergic people, but often cyanobacteria are also present in this biomass, which is somewhat worse. [123]

Fig. 122 Aquatic bloom of water surface lake - Municipal district Nad Jazerom, Košice, Slovakia

In our conditions, it manifests itself mainly in the summer period, when it creates hygiene problems in swimming pools and reservoirs that were originally intended as a source of drinking water (increased costs for the renewal of mechanical filters and the removal of toxins from the water). In full development, the aquatic bloom forms a dense carpet, particularly along the banks and in quiet bays. In addition to the toxins produced by the cyanobacteria, the decomposition of biomass results in putrefactive processes associated with oxygen depletion. The production of toxins often causes skin allergies, conjunctivitis, bronchitis and the possibility of poisoning in humans, but it has recently been discovered that toxins could also have positive uses. [110]

Toxins can also be used as cytotoxic antibiotics with anticancer effects. Cyanobacteria are very rich in protein content, containing 60 – 70 % on a dry weight basis. In many countries, Arthrospira (Spirulina) (Fig. 123) is grown in large-scale culture facilities.

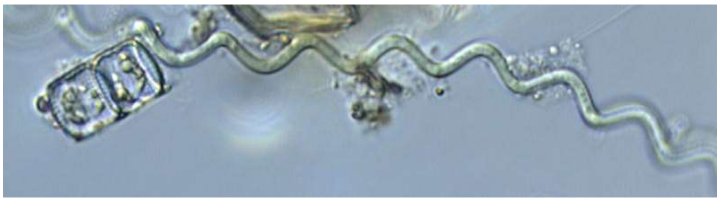


Fig. 123 Spirulina (800x) [123]

Its dry matter is mainly used for its easy digestibility, carotene and vitamin content, of which vitamin B is the highest of all known sources of this substance. Spirulina and other cyanobacteria are sources of phycobiliproteins, especially blue phycocyanin. It is used as a non- toxic dye and in many cases replaces radionuclides in medicine. It is widespread in cyanobacteria formation of sediments in the form of muddy deposits - peloids, often used for therapeutic purposes. The beneficial effects on musculoskeletal disorders (Fig. 124) are mainly due to the mineral and organic content. [110]

Fig. 124 Beneficial effects of peloids [123]

In thermal spas, cyanobacteria are involved in the formation of healing peloid, used for spa treatment.

6.10 Overview of the Current Status of Reservoirs in Slovakia

The quality of bathing waters as well as the hygienic conditions of natural recreational areas and swimming pools in Slovakia are monitored by the Public Health Office of the Slovak Republic (ÚVZ SR) and 36 Regional Public Health Offices (RÚVZ), which provide within their scope of competence and the exercise of State Health Surveillance [123]:

- monitoring the quality of bathing water,
- issuing instructions to remedy identified deficiencies,
- imposing sanctions.

With the accession of the Slovak Republic (SR) to the European Union (EU), our country has committed to submit an annual report on the quality of bathing areas after the end of the bathing season. The results of the monitoring and the NWT are evaluated by the ÚVZ SR, which uses the processed results to prepare a Report on the readiness of bathing waters for the next summer tourist season (LTS), which is submitted to the European Commission (EC) and the Slovak Environmental Agency (SAŽP).

Bathing water readiness reports had to 2008 be produced by the year and meet the requirements of **Directive 76/160/EH**. Since this year, the Water Quality Reports have been prepared in accordance with the new **Directive 2006/7/EC**. Each year, the Slovak Republic must also establish a list of bathing waters before the start of the bathing season and include them in the monitoring programme under this Directive. The Slovak Republic is also obliged to submit this list of waters to the European Commission. [120]

During the 2011 - 2022 monitoring period, cyanobacterial water blooms were recorded at 16 sites per year (Fig. 125). During the monitoring of recreational waters, the occurrence of cyanobacterial water blooms was detected at the sites of Zemplínska Šírava, Vinianske lake, Lake in Košice, Čaňa, Liptovská Mara, Ľadovo and Ružiná reservoirs; water blooms were also found at Kuchajda gravel pit in Bratislava, Kanianka, Suchá nad Parnou and Oravská lake reservoirs. The specific species of cyanobacteria at the sites are listed in (Tab. 20).

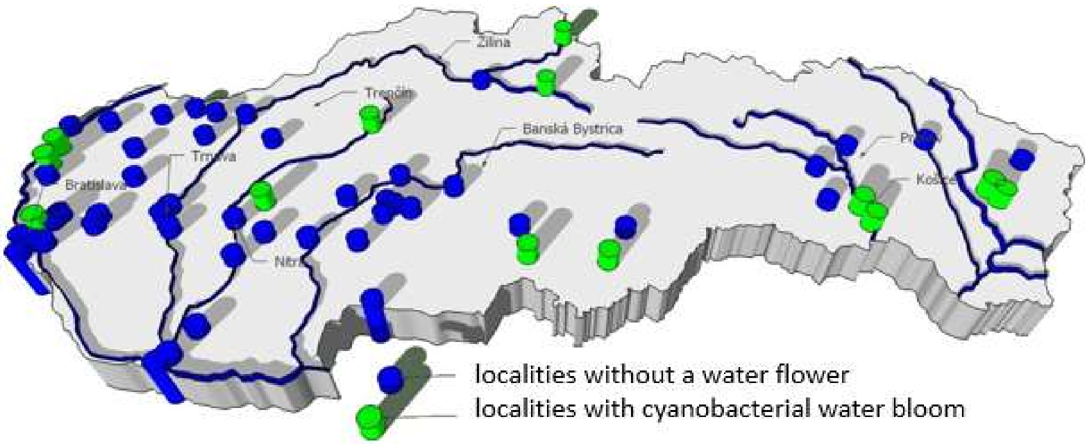


Fig. 125 Map of sites with occurrence of cyanobacterial water bloom in the year 2020 [123]

Tab. 20
Occurrence of cyanobacterial species in selected localities in Slovakia, in year 2020

Location	Types of cyanobacteria	Location	Type of cyanobacteria
Čaňa	*Anabaena sp.* *Aphanizom.flos-aquae* *Microcystis flos-aquae*	**Oravská Priehrada**	*Microcystis aeruginosa* *Woronichinia naegeliana*
Liptovská Mara	*Anabaena spiroides* *Aphanizomenon flos-aquae* *Microcystis aeruginosa* *Microcystis viridis* *Woronichinia naegeliana*	**Ružinná**	*Microcystis aeruginosa* *Microcystis flos-aquae* *Microcystis viridis* *Microcystis wesenbergii* *Woronichinia naegeliana*
Kanianka	*Planktothrix rubescens*	**Suchá nad Parnou**	*Anabaena planctonica* *Aphanizomenon*
Kuchajda in Bratislave	*Aphanocapsa incerta* *Microcystis aeruginosa* *Microcystis flos-aquae* *Microcystis viridis* *Microcystis wesenbergii* *Woronichinia naegeliana*	**Vinianske jazero**	*Microcystis aeruginosa* *Microcystis flos-aquae* *Microcystis wesenbergii*
Ľadovo	*Anabaena sp.* *Anabaena spiroides* *Microcystis aeruginosa* *Woronichinia naegeliana*	**Zemplínska Šírava**	*Anabaena sp.* *Aphanizomenon sp.* *Microcystis aeruginosa* *Microcystis flos-aquae* *Microcystis viridis*
Kráľová n/Váhom–Kaskády	*Anabaena sp.* *Microcystis aeruginosa*	**Gazarka in Šaštíne**	*Microcystis flos-aquae* *Microcystis wesenbergii*
Kunov	*Microcystis aeruginosa* *Woronichinia naegeliana*	**Bátovce – Lipovina**	*Anabaena sp.* *Aphanizom.flos-aquae* *Microcystis flos-aquae*
Jazero – Košice	*Aphanizom.flos-aquae*	**Šáhy – health area**	*Aphanizom.flos-aquae* *Microcystis flos-aquae*

An indicator of the trophic state of the waters expressing the amount of phytoplankton biomass is the amount of chlorophyll “**a**”. According to the “**Methodology for the determination and assessment of chlorophyll a concentrations in surface waters”,** water with a chlorophyll a concentration above 25 $mg.m^{-3}$ assessed as strongly eutrophic, unsuitable for recreational purposes (Tab. 21).

Tab. 21

Selected water quality indicators in lakes and reservoirs in the Slovak Republic, assessed as natural bathing areas, in the year 2020

Name of location (district)	Area (km²)	Min. clarity (m)	$N_{anorg.}$ ($N-NO_3^+$ $N-NO_2^+$ $N-NH_4^-$) ($mg.1^{-1}$)	$P-PO_4$ ($\mu g.1^{-1}$)	Chlorophyll a max. value ($mg.m^{-3}$)	Saprobity index
ŠJ Ivánka pri Dunaji (BA)	0,075	-	0,01	-	-	1,71
ŠJ Kuchajda v Bratislave (BA)	0,08	-	0,11	-	26,7	1,94
ŠJ Zlaté piesky (BA)	0,56	-	0,01	-	-	1,81
ŠJ Rovinka v Bratislave (BA)	0,56	-	0,002	-	-	1,73
ŠJ Jakubov (MA)	0,2	-	0,1	-	-	1,88
ŠJ Plavecký Štvrtok (MA)	0,12	-	0,07	-	-	1,82
ŠJ Slnečné Lakes Senec (SC)	0,16	-	0,06	-	-	1,9
VN Kráľová n/Váhom – Kaskády (GA)	10,89	0,5	0,21	-	46,3	-
VN Kunov (SE)	0,63	0,9	***0,19	-	27,63	2,03
ŠJ Gazarka v Šaštíne (SE)	0,12	0,8	***0,18	-	29,4	1,93
ŠJ Zelená voda – Nové Mesto n/Váhom (NM)	1,1	1,5	**5,9	*<0,034	1,9	1,8
ŠJ Veľký Cetín 1 (NR)	0,082	1	***0,098	-	-	1,6
VN Vráble – centre (NR)	0,48	0,25	1,42	-	-	1,8
VN Jelenec – centre (NR)	0,073	0,3	0,44	-	-	1,8
VN Bátovce – Lipovina (LV)	0,265	-	0,29	-	44,55	2,2
ŠJ Šáhy – health area (LV)	0,023	-	1,38	-	80,8	1,98
ŠJ Komjatice (NZ)	taken out of tracking					
ŠJ Šurany – Tona (NZ)	0,18	-	0,08	-	-	1,95
VN Duchonka (TO)	0,139	0,3	3,155	0,138	-	1,81
VN Liptovská Mara – Lipt. Trnovec (LM)	21,68	0,4	1,62**	*0,26	49,8	1,8
VN Oravská priehrada – St. Hora (NO)	3,5	1,0	1,653	26,6	27,4337	1,96
VN Ružiná – near the village Ružiná (LC)	1,7	0,8	1,04	-	18,06	1,88
VN Kurinec – Zelená voda (RS)	0,25	0,5	0,326	*0,072	14,77	1,92
VN Teplý Vrch (RS)	0,7	1,1	0,277	*0,021	15,43	1,74
BJ Klinger (BŠ)	0,017	0,7	***0,311	ND	0,00996	1,89
BJ Veľké Richňavské lake (BŠ)	0,076	1,5	ND	ND	0,0033	2,21
BJ Počúvadlo (BŠ)	0,117	1,2	***0,3105	ND	0,00395	1,84
BJ Dolné Hodrušdké lake (ZC)	0,049	1	0,155	0,022	0,00354	1,78
ŠJ Čaňa (KS)	0,42	0,6	1,31	ND	60,2	2,92
VN Lake in Košice (KE)	0,13	0,3	0,66	0,078	56,1	1,8
VN Bukovec (KS)	0,279	1,5	1,1	0,027	8,44	1,79
VN Lake Vinian (MI)	0,08	0,4	2,22	0,2	64,39	1,67
VN Zemplínska Šírava – Biela hora (MI)	33,6	0,3	2,2	0,12	89,71	1,86
VN Zemplínska Šírava Hôrka (MI)		0,5	1,93	0,1	880,142	1,1
VN Zemplínska Šírava – Medvedia Hora (MI)		0,4	20,4	0,1	682,5	1,96

Explanatory notes: BJ - mining lake, VN - water reservoir, ŠJ - gravel lake, ND - not detected

** value of total phosphorus, ** value of total nitrogen, *** value of ammoniacal nitrogen Source*

The highest maximum values of chlorophyll "**a**" (Fig. 126) during the bathing season were recorded in the areas of Čaňa (60,2 mg.m^{-3}), Ľadovo (60,86 mg.m^{-3}), Šahy - Areál zdraví (80,8 mg.m^{-3}), Šahy - Areál zdraví (80,8 mg.m^{-3}), Šahy - Areál zdraví (80,8 mg.m^{-3}), Vinian Lake (64,39 mg.m^{-3}), Zemplínska Šírava - Hôrka (880,142 mg.m^{-3}), Zemplínska Šírava - Kamenec (604 mg.m^{-3}), Zemplínska Šírava - Medvedia Hora (682,5 mg.m^{-3}), Zemplínska Šírava - Palkov (132,86 mg.m^{-3}).

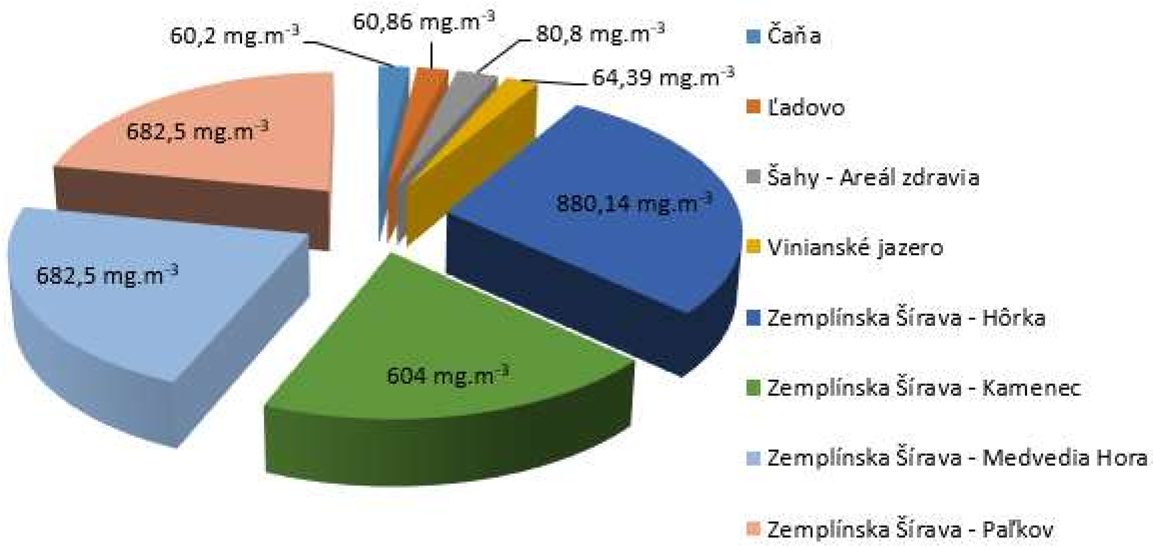


Fig. 126 Highest maximum chlorophyll "a" values [123]

6.11 Methods to Eliminate Cyanobacteria on Water Reservoirs

There are several methods of dealing with this, ranging from preventive methods to measures that deal with the consequence of excessive cyanobacterial growth. Most of the methods in use today are a burden on the environment or are too costly to implement. The choice of the appropriate method depends on the size and purpose of the water body. The most effective time to intervene against mass cyanobacterial growth is at the beginning of the cyanobacterial growth or early in the summer season, when they are most vulnerable and weakened after overwintering. A number of factors are involved in the formation of the cyanobacterial bloom, such as (pH, temperature, solar radiation, oxygen content as well as carbon dioxide content, etc.). In addition to these factors, it is very important to know the amount of mineral nutrients, namely nitrogen and phosphorus. These mineral nutrients are the main reason for cyanobacterial overgrowth in the first place. Phosphorus in particular is considered to be a limiting factor. The best results in the fight against cyanobacteria are achieved by a combination of methods. Methods for limiting the development of aquatic cyanobacterial blooms (Fig. 127) include, for example [123].

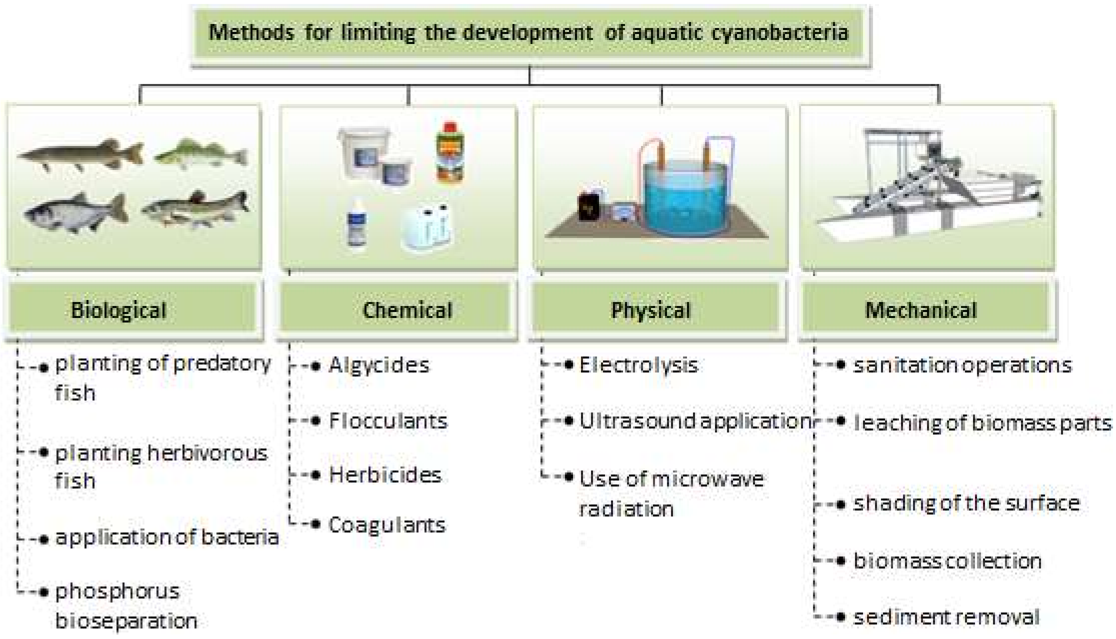


Fig. 127 Methods of limiting cyanobacterial development [123]

6.11.1 Biological Method for Removing Cyanobacteria

The most suitable method for cyanobacteria control appears to be the biological method, where the intensity of primary phytoplankton production can be influenced by appropriate stocking, thus positively altering the development of phytoplankton, zooplankton, and pond or lake bottom fauna. [123]

Landing of predatory fish

If there are large numbers of plankton-eating fish in the tank, the zooplankton are so suppressed that there is not enough of them to effectively reduce cyanobacteria. The effect of introducing predatory fish as a tool in the fight against cyanobacteria is based on limiting the number of plankton-eating fish. The most commonly stocked predatory fish are pike, e.g. northern pike (*Esox lucius*) (Fig. 128), and zander, e.g. largemouth bass (*Stizostedion lucioperca*) (Fig. 128).


Šťuka severná


Zubač veľkoústy


Sumec veľký


Cendát obecný


Bolen dravý

Fig. 128 Predatory fish [123]

Planting herbivorous fish

Herbivorous fish feed mainly on small phytoplankton, which they filter out of the water. The most effective herbivorous fish include the white mullet (*Hipophthalmichthys molithrix*) or the variegated mullet (*Aristichthys nobilis*). When cyanobacteria are reduced, macrophyte development increases. To limit macrophyte development, the white abalone (Fig. 129) is planted in combination with the white amur (*Ctenopharyngodon idell*) (Fig. 129) at a ratio of 1:3. The stocking of the fish is phased over a 3-year period.

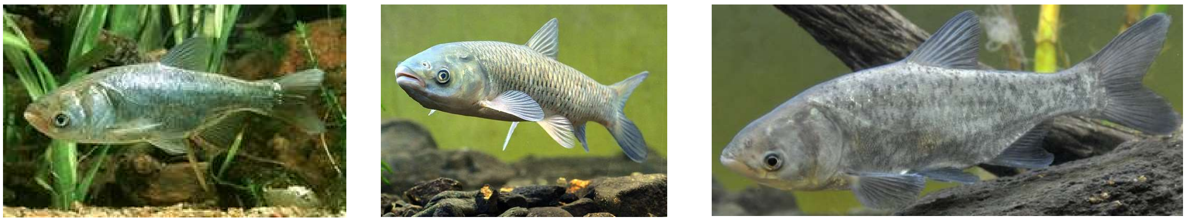


Fig. 129 Herbivorous fish [123]

The food chain (Fig. 130) can be regulated by biomanipulation measures [110]:

- promoting the presence of predatory fish to limit the abundance of zooplankton-eating fish species, limiting the abundance of zooplankton-eating fish species by increasing their catch,
- planting herbivorous fish species to control cyanobacteria development,
- planting herbivorous fish in the case of excessive spread of higher aquatic plants,
- the creation of suitable conditions for the reproduction of desirable fish species.

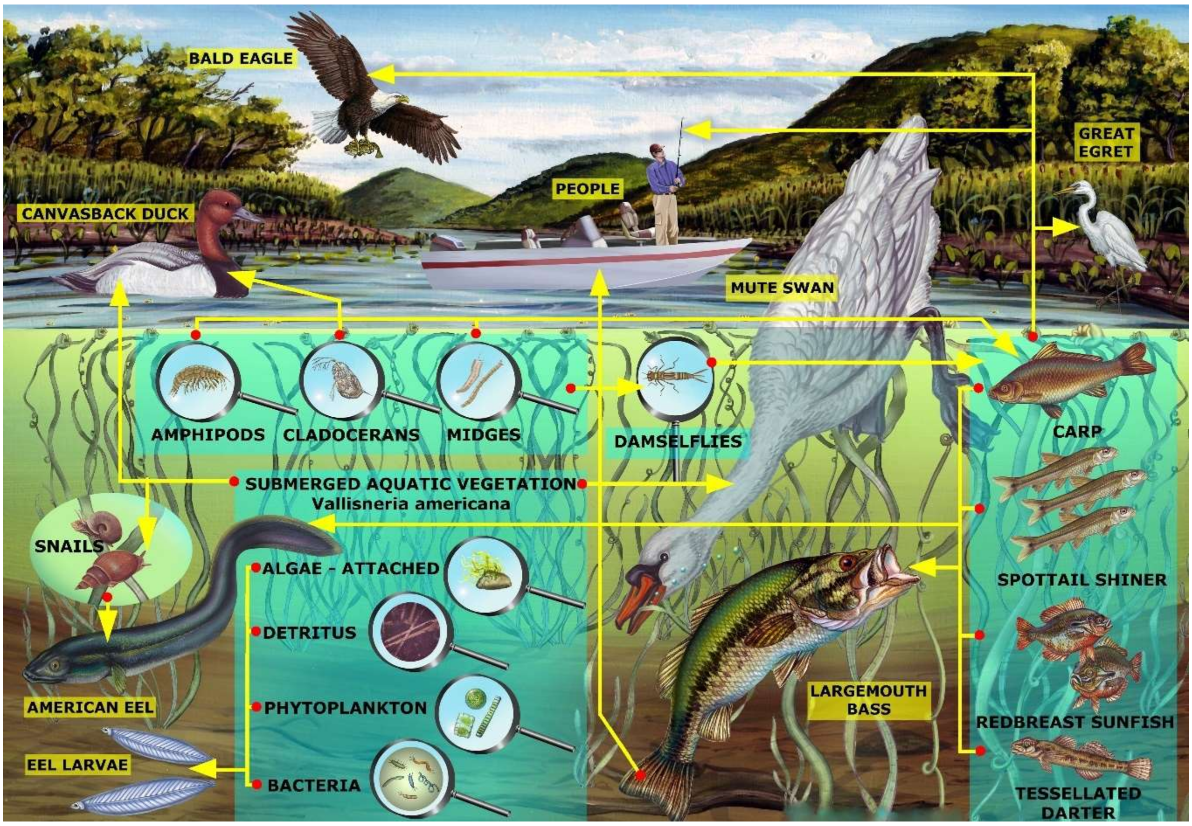


Fig. 130 Food chain [127]

Another method to eliminate cyanobacteria is bacterial application (Fig. 131), which is a direct biological control, where the action of living organisms such as: viruses, bacteria, fungi and fungal organisms, algae, protozoa are used to eliminate the aquatic bloom.

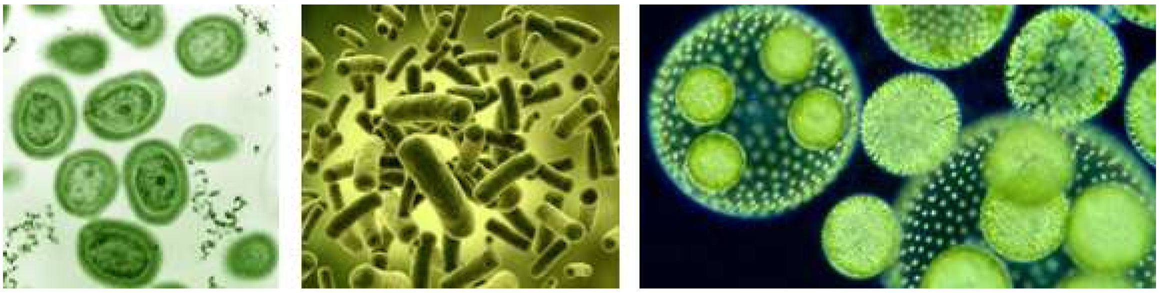


Fig. 131 Application of bacteria [123]

Biotic interactions represent a direct biological control where the action of living organisms is used to limit aquatic blooms. These include:

- **viruses** (cyanophages) that cause cyanobacterial mortality, the most well-known cyanophages include SM - 1 and SM - 2, yet they have not yet been used directly for biological control in the tank for laboratory purposes only (Fig. 132). Cyanobacteria become resistant to viruses after 40 days),

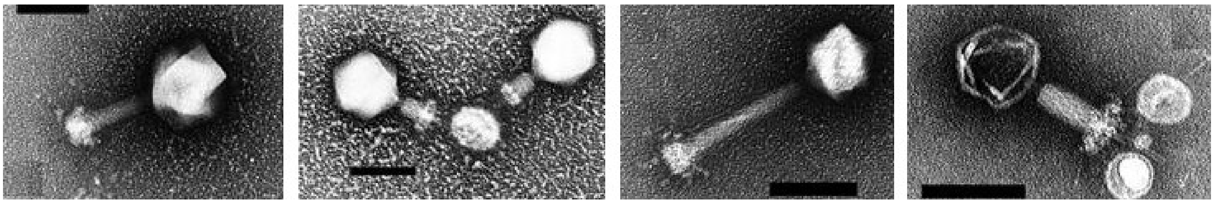


Fig. 132 Cyanophages [123]

- **bacteria** (limit the massive growth of cyanobacteria by ingesting parts of the nutrients or by using degradable enzymes, thereby disrupting their cell wall and preventing certain biochemical processes, including photosynthesis (Fig. 133). These include Actinomycetes, Bacillus sp., Flexibacterium, Pseudomonas sp.),

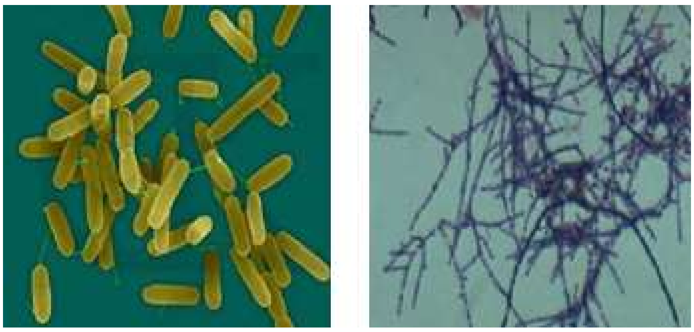


Fig. 133 Bacteria Pseudomonas, Bacillus sp. [123]

- **fungal organisms** (order Chytridiales, which can parasitise cyanobacteria) (Fig. 134).

Fig. 134 Chytridiales parasitizing cyanobacteria [123]

- **protozoa** (from previous studies, the consumption of cyanobacteria of the genus Anabaena by bryozoans has been observed. Successful consumption of cyanobacteria by protozoa is only possible by very close contact between the animal and the food and by the appropriate size of the protozoa to the food),
- **algae** (by producing so-called allelopathic substances, they suppress the growth of cyanobacteria).

6.11.2 Chemical Method for Removing Cyanobacteria

The most commonly used method for controlling cyanobacteria is the chemical method, which can eradicate the biomass. This method is only suitable for small reservoirs. The most common chemicals used to eliminate biomass are: algaecides, flocculants, herbicides and coagulants (Fig. 135).

Fig. 135 Commercial chemical preparations for biomass elimination [123]

Algicides

The most common algicidal agents are copper sulphate (blue rock - a carcinogen), aluminium compounds, ferric chloride, calcium hydroxide and ferrous sulphate. The advantage of algaecides is mainly low cost and rapid effect, but the big disadvantage is the short-term effect, the accumulation of copper in the sediment and the effectiveness of which, is influenced by the composition of the water. When algicides are applied, the cyanobacteria cells are killed and the cellular contents are poured into the water. This almost invariably leads to oxygen deficiency, extremely elevated dissolved organic matter in the water, and the release of toxins that affect the taste and odour of the water. Water bodies after algaecide application cannot be used as a source of drinking water or for recreational purposes. The use of algaecides is restricted or prohibited in certain countries. [123]

Herbicides

Any application of herbicides should be avoided as far as possible. Indeed, when herbicides are applied, we can never rule out some accumulation in the food chain, which means a hidden threat not only to the ecosystem of the reservoir, but also to humans! [123]

Flocculants

The advantage of flocculants is that, unlike algaecides, there is no release of toxins. Recently, the global trend has been towards flocculants made from natural raw materials or biological waste from seafood processing (so-called chitosan-based products). These products are biodegradable and therefore do not pollute the environment. [123]

Coagulants

Coagulants are organic substances that neutralize the surface charge of particles in water, thus allowing them to clump together into larger units. Clarification takes advantage of the observation that cyanobacterial cells are well absorbed on freshly formed flakes of ferric or aluminium hydroxide. [123]

6.11.3 Physical Method for Removing Cyanobacteria

The use of ultrasound

In the fight against the mass occurrence of cyanobacteria and algae, the ultrasonic method has recently been used (Fig. 136). Ultrasound destroys heterocytes, attacks special cells in the cyanobacterial filament where the fixation of air nitrogen takes place, which, among other things, due to the gases contained, act as floaters. The ultrasound wave from the ultrasound transducer causes the gas in the heterocytes to resonate and the affected heterocytes eventually float. The cyanobacterial filaments then sink helplessly into the darkness, which quickly kills them. [110]

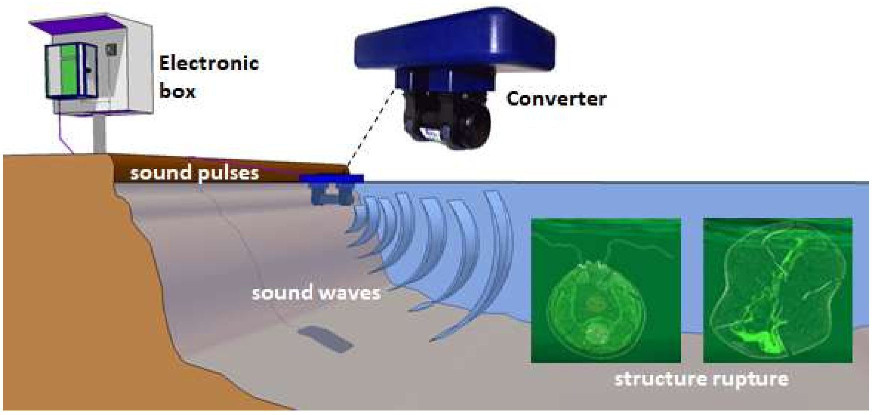


Fig. 136 Schematic of the ultrasound system

The ultrasound can be fine-tuned to a specific type of cyanobacteria. In this case, it is a clean technology that more or less does not harm other organisms. Moreover, ultrasound will only destroy heterocytes, because the other cells of filamentous cyanobacteria are full of water and as such resist the ultrasound pulses quite well. This is very handy, because the destruction of all the cells of the water bloom cyanobacteria would wash a huge amount of neurotoxins into the surrounding water.

This method is only suitable in fresh water and only on smaller bodies of water. Water absorbs ultrasound extremely efficiently and the effective range of 1 MHz ultrasound in water is only 20 m.

Electrolysis

Electrolysis (Fig. 137) is a physico-chemical process caused by the passage of an electric current through a solution, in which chemical changes occur at the electrodes. An electrically conducting solution contains a mixture of positive and negative ions, which are formed by the dissociation of molecules. The passage of an electric current results in the movement of positive ions (cations) to the negative electrode (cathode) and negative ions (anions) to the positive electrode (anode). Chemical reactions can take place at the electrodes in this way - between the ions and the electrode, between the ions themselves, or between the ions and the solution (due to the higher concentration of ions at the electrodes). In the electrolysis of water, oxygen O_2 is evolved at the positive anode electrode and hydrogen H_2 is released at the negative cathode electrode. The method is used to reduce P and N in water. [110]

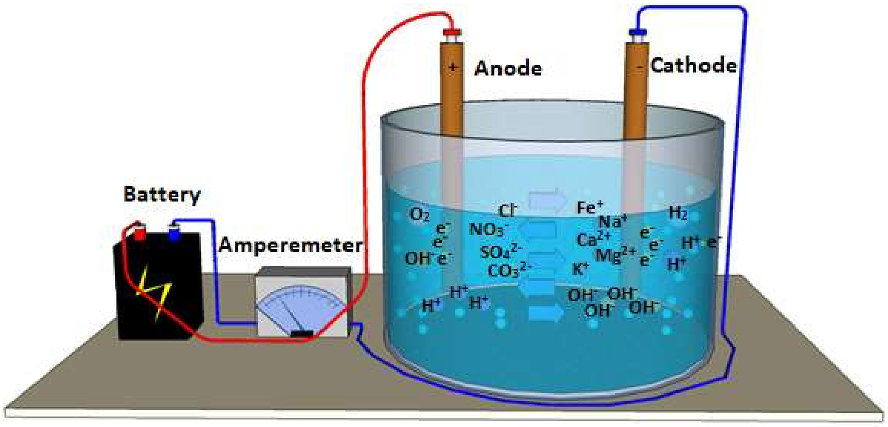


Fig. 137 Electrolysis process

In the electrolysis of water, chemical reactions take place at the electrodes [120]:

- at the positive electrode (anode): $2\ OH^- \rightarrow H_2O + ½\ O_2 + 2e^-$
- at the negative electrode (cathode): $2\ H_2O + 2e^- \rightarrow 2\ OH^- + H_2$
- the resulting electrolysis reaction: $H_2O \rightarrow H_2 + ½\ O_2$

The released gases are secreted in fine bubbles. The size of the bubbles is controlled by changing the intensity of the electric current.

The basic electrolytic processes for cyanobacteria disposal include [120]:

- electro-flotation,
- electro-coagulation.

Electro flotation (Fig. 138) is a physicochemical process that uses the surface of the hydrogen or oxygen bubbles that are formed during electrolysis. The air bubbles are absorbed by the cyanobacteria cells with oppositely charged ions and form a foam on the surface.

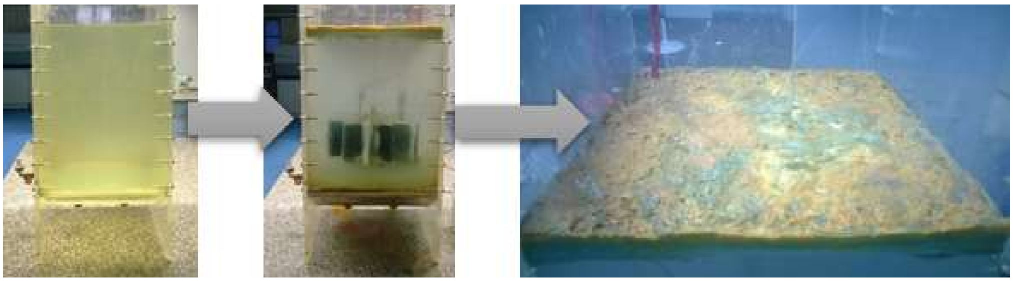


Fig. 138 Electro flotation

Advantages: elelctro flotation are:

- higher monodispersity of bubbles whose size is 50 to 70 µm,
- perfect distribution of bubbles in the water,
- the oxygen produced oxidises substances in the polluted water.

The disadvantage of electro flotation is its energy consumption.

Electrocoagulation is the process by which cyanobacterial cells precipitate with ions dissolved in water from a soluble anode following the passage of an electric current. Electrocoagulation uses the process of electrolysis to generate coagulant by anodic oxidation. Anodes of aluminium or iron are used. On the anode, the metals are dissolved: $Al \rightarrow Al^{3+} + 3\ e$ or $Fe \rightarrow Fe^{3+} + 3\ e^-$. At the appropriate pH, hydrolysis of the aluminium or iron salts produces the corresponding hydroxides.

The efficiency of electrocoagulation depends on [120]:

- water quality,
- current density,
- the residence time of water in the inter-electrode space,
- type of electrodes,
- electrode distances.

6.11.4 Mechanical Method for Removing Cyanobacteria

Mechanical removal of the produced biomass is only an option in locations where there is a temporary accumulation of water bloom.

Biomass collection

Dense nets or synthetic fabrics are used for biomass collection (Fig. 139), but there is a problem with their subsequent storage and drying. The cyanobacterial biomass smells unpleasant when drying. This mechanical method is only effective for small water tanks.

Fig. 139 Mechanical biomass removal using net [120]

Oxidation of sediments

Artificial aeration compensates for the lack of oxygen caused by a greater supply or higher production of organic decomposable matter. In lakes, reservoirs and ponds, the dispersed aeration method is applied.

The diffusion aeration pipe is very well suited for lakes and ponds, where a diffusion aeration system is required. This pipe is a unique double aeration self-contained pipe made of thermoplastic elastomer. The primary pipe has a large number of fine laser-formed holes that produce and regulate a continuous stream of very small air bubbles. Their size ranges from 6 mm to 30 mm depending on the pressure. A secondary pipe filled with environmentally friendly silica sand serves as ballast.

The device is conveniently placed on the bottom and is pressurized with a low-pressure compressor. Tiny bubbles escaping from the diffusion aeration pipe rise slowly from the bottom at a velocity of less than 20 cm per second (laminar flow). At this rate of rise, bubbles do not cause turbidity. As the bubbles rise, they expand and therefore consume energy. In this way, aeration gently lowers the water temperature, and this is the first step in destroying cyanobacteria and algae deposits in the water. It is known that the colder the water, the more oxygen and ozone it contains, which allows the oxidation chemical process. This process is actually a kind of cold combustion that consumes the chemical compounds contained in the water and sediments. These sediments decompose naturally and lower order compounds and subsequently become food for aquatic organisms and animals. [123]

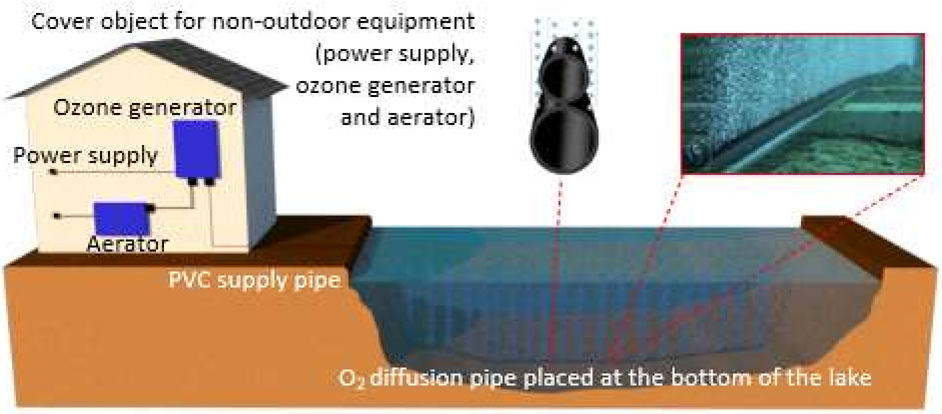


Fig. 140 Schematic diagram of the diffusion aeration system

Once the diffused aeration system (Fig. 140) is in place, beneficial bacteria can be added to the water. Different strains of bacteria ingest the nutrients, breaking them down into carbon dioxide and water, as well as inactive ash and simple elements. The cells of these bacteria then become part of the food chain, providing food for zooplankton and small insects, which are then eaten by larger animals such as fish and birds. In this way, the nutrient supply from the lakes is diverted from plants and algae to higher life forms and the natural ecosystem cycle of plants and animals is established.

Diffusion discs with rubber-rubber membrane are suitable for large lakes, reservoirs, garden tanks, ponds and industrial use (wastewater treatment plants). It is a very environmentally friendly solution without the use of chemical products. This method is very effective but very expensive. The aeration system (Fig. 141) consists of two diffusion discs, permanently anchored by concrete weights to the bottom. A compressor on the shore supplies the aerator with compressed air through a hose lying on the lake bottom. The air stream is fragmented by the diffuser into small air bubbles, which rise and induce a flow of water towards the surface (principle of a hydropneumatic pump). The air flow rate is 133 l/min. During this intense contact of the air bubbles with the water and when the water is in contact with the air, oxygen is transferred to the water. [123]

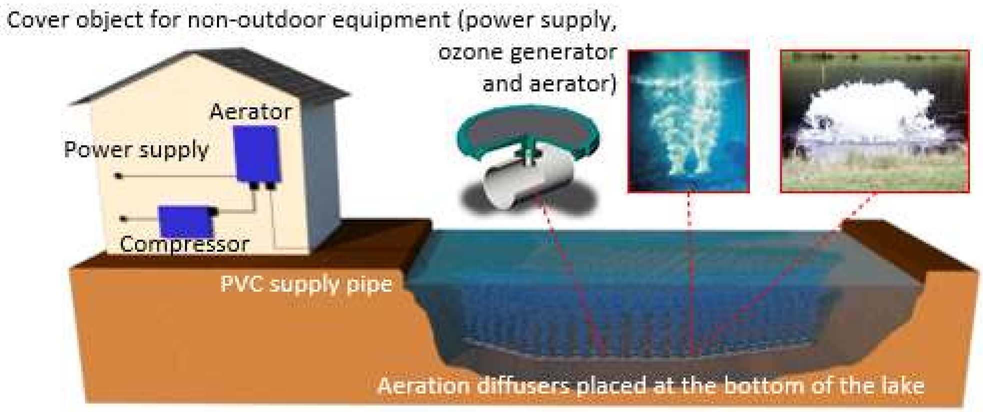


Fig. 141 Schematic of the diffusion disk system

Remediation measures at the bottom of tanks

One of the mechanical methods to limit nutrient inputs is through remediation measures at the bottom of the basins (Fig. 143). Sediments are the main source of nutrients in reservoirs. Cyanobacteria colonies can overwinter in shallow tanks (layer 0 - 5 cm) at sediment temperature 8 °C and oxygen 3 mg/l. The Nostilus suction excavator is shown in Fig. 142.

Fig. 142 Suction excavator Nostilus [120]

Fig. 143 Remediation operations at the bottom of the tank [120]

The principle of the method is based on the dredging of the bottom of a reservoir or lake, i.e. by excavation of various non-cohesive material (by suction dredging from the water surface or by dredging after draining the reservoir). By removing the top layer of sediment with the highest phosphorus content, it ensures a reduction in phosphorus reserves and thus increases the efficiency of the method. The greatest advantage is the removal of a significant part of the cyanobacteria together with the sediment in which they are permanently present.

A serious problem arises in the placement of the excavated sediment when a suitable area is allocated for its placement. The method of sediment removal depends on a number of indicators (fines, agricultural use, nature of the bed, degree of contamination, possibility of extraction). The disadvantage is the time and cost involved, so this method is more suitable for smaller lakes. Prior to the actual extraction, a study of the vertical structure must be carried out to determine the exact layer of sediment to be removed. Sediment removal is carried out with a steel probe, which takes a vertical profile of the sediment, preserving the original structure and volume. Toxic substances are then determined according to established standards. If the results do not show the presence of toxic substances, the sediments can be used for agricultural purposes. [120]

Shading of the surface

Unwanted development of algae and cyanobacteria can also be suppressed by shading the surface. This method is rarely used in practice and is only suitable for domestic lakes or garden tanks. Riparian vegetation or screens (Fig. 144) are most commonly used to provide sufficient shading.

Two types of shading are known [123]:

- partial shading (at least one half is recommended),
- completely overshadowing.

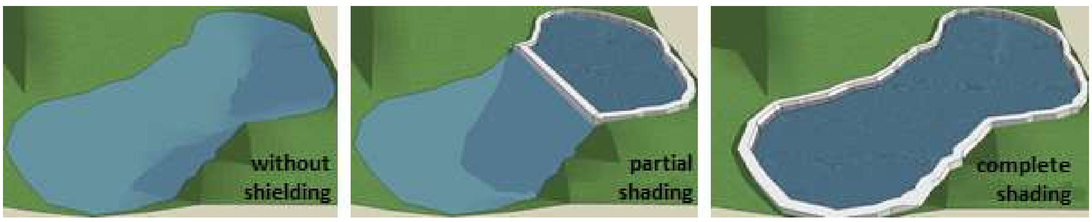


Fig. 144 Level shading

Shading of the water surface will ensure that temperature extremes during both summer and winter are moderated, which can have serious consequences for organisms, especially fish, in certain circumstances. Shading ensures a reduction in the intensity of solar radiation reaching the water surface, thereby reducing the photosynthetic processes of algae and cyanobacteria and thus eliminating the process of reducing the dissolved oxygen concentration in the water, which is necessary for fish communities. [123]

Removal of biomass from the water surface using vessels

For this method, a non-chemical principle of biomass removal is used, namely mechanical separation. The technology is based on the collection of biomass from the water surface and the separation of biomass particles on a mechanical filter, whereby the biomass contains a large amount of nutrients that would otherwise be deposited as organic matter in the bottom sediment (Fig. 145).

The filtered water can be further treated before it is discharged back into the tank by another technology working on a physical principle that destroys, for example, the cyanobacteria that have passed through the filter. The extracted cyanobacteria are stored on board the vessel in a container which is unloaded on shore and transported for environmentally friendly disposal.

This technology does not introduce any contaminants into the water and the whole principle is extremely environmentally friendly. By removing biomass from the water reservoirs, potential nutrients in the sediments are reduced. [123]

Fig. 145 Types of vessels for the separation of biomass particles from the surface of the water surface

6.12 Methodology for Exact Monitoring of the Impact of Technology and Equipment for the Revitalization of Stagnant Waters

The design of the methodology for monitoring the impact of the technology is based on the principle of electrophlolotation, which was developed at the Department of Environmental

Engineering at the Technical University of Košice. This department has been engaged in wastewater treatment by electrolytic method using the project VaV ŠF EU ITMS: **26220220028 "Implementation and modification of technology to reduce the occurrence of sieves in stagnant waters"** and also holds a patent for an electrolytic wastewater treatment plant with rotating electrodes registered with the Industrial Property Office of the Slovak Republic (ÚPV SR).

6.12.1 Sampling

The first step before determining the sieveds and algae from the biosestone is to take samples from the area under investigation using a device.

The following can be used for sampling [120]:

- open level sampler (open estuary containers for surface water level sampling),
- closed tubular sampler (hollow container equipped with a cap or valve to obtain samples from a certain depth).

In order not to react between the stencil material and water, it is necessary to use stainless steel, glass or plastic stencil. At the sampling point, a sample shall be taken from stagnant waters to determine the sieved and algae from a depth horizon of 0 - 30 cm. According to the dispersion of siemias and algae at the site examined, it is more efficient to take an integrated sample (incremental samples within a sampling point of up to 4 m). The sampler is nested in a water column to a depth of 30 cm, where it is closed. Subsequently, the incremental samples in the sampler are mixed and erred into the stencil (Fig. 146) [120].

"The optimal time for sampling is between 6:00 and 11:00, as at that time the sieps and algae are able to regulate their position in the water column".

Fig. 146 Tubular water sampling sampler [120]

Teh Fig. 147 below shows the test for the presence of sulps, as well as the high and low biomass of the sieps.

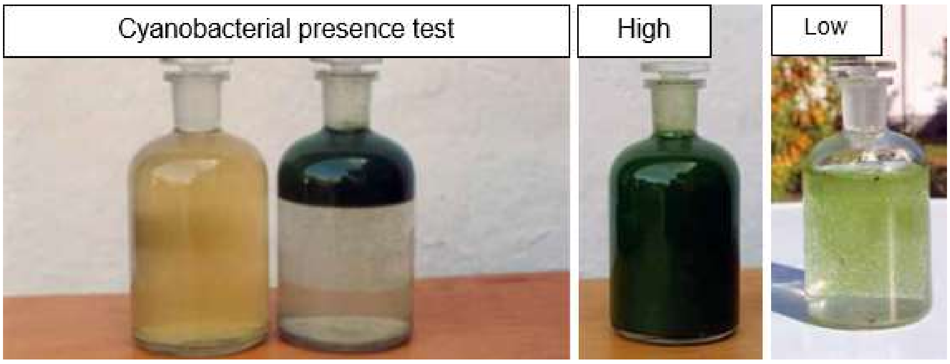


Fig. 147 Cyanobacterial presence test and high and low cyanobacterial biomass

Sampling of water for biological analysis shall be performed in accordance with the requirements of the relevant standard, taking into account the purpose of the analysis. Pure glass sample boxes (Fig. 148) are used for sampling and filled to ¾ volume so that oxygen is available in the sample box. They are transported in refrigerated bottles and processed immediately, but no later than 24 hours after collection, in order to avoid quantitative changes. The samples are stored at 4 °C until processing and must be tempered at ambient temperature (approximately 20 °C) before analysis. During transport, samples must be tightly closed before losing part of their volume. [120]

Fig. 148 Glass container for sampling

The shortest time interval for water quality control is 1 week and the longest acceptable interval is 1 month. The water quality can also change during the day (inflow of water into the tank), so it is important to take samples at the same time and in the same place throughout the examination. [120]

6.12.2 Determination of the Number of Cyanobacteria and Algae from the Biosestone

In the biological analysis of aquatic organism communities, an attempt is made to identify and specify all the organisms present in the sample taken. This requires both the determination of the species composition of the biocenosis, which is referred to as qualitative biological analysis, and the precise determination of the number of organisms per unit volume, i.e. quantitative analysis [128].

The number of methods developed to quantify biosestone in water is, of course, large, differing in accuracy, purpose and complexity. In principle, they should pursue two objectives: to be sufficiently precise, but at the same time simple and, of course, routinely applicable. The procedure for quantitative analysis to assess the quality of drinking water, raw drinking water before and after treatment and surface water, which requires compliance with the criteria, is prescribed by standard STN 75 7711: Water quality [129]. Biological analysis. Determination of biosestone. The subject is a quantitative expression of the community of all living organisms present in the water column (**biosestone**).

The sequence of steps in determining the amount of organisms in the water is as follows: sampling, transport of samples, laboratory processing of samples (sample concentration, counting of organisms) and evaluation of results. It is important to work with precisely defined sample volumes, which is a necessary prerequisite for accurate quantification of organisms per unit volume [130].

6.12.2.1. Sample Concentration Methods

There are usually too few organisms in a non-concentrated water sample to give an accurate picture of their qualitative and quantitative representation. Therefore, in the laboratory conditions, it is necessary to concentrate the organisms in the sampled sample before the quantitative analysis itself. In principle, three basic ways of concentrating organisms are known [128]:

- sedimentation,
- centrifugation,
- membrane filtration.

Sedimentation

The organisms present are allowed to sediment in a certain precisely determined volume of the subsamples, the sedimentation time depending on the number of organisms and the volume chosen. Sedimentation takes place in different types of sedimentation chambers and the resulting analysis is usually performed using an inverted microscope. This type of concentration and quantification significantly eliminates the introduction of errors into the results of the analyzes, but it works with organisms preserved with Lugol's solution or formalin. The method of quantification of organisms on sedimentation chambers is described in STN EN 15204: Water quality [131]. Instructions for the determination of phytoplankton by inverse microscopy (Utermöhl method) and its publication and subsequent implementation of this procedure in practice are also being prepared in Slovakia.

Centrifugation

During centrifugation, the organisms are concentrated in a certain volume of the sample by the action of centrifugal force. The result is concentrated organisms in the sediment at the bottom of the centrifuge tube. Currently, it is the most widely used method of concentration of organisms, prescribed by the valid STN 75 7711: Biological analysis. Biosestone determination [129].

The centrifugation time and the number of revolutions required to centrifuge the organisms into the sediment vary depending on their size, relative weight and the natural distribution of the organisms in the water column. Larger species, which are part of benthos, for example, and enter the open water secondarily, concentrate faster (e.g. some diatoms), while the time and speed required to concentrate small planktonic species are greater. However, too long a centrifugation time or too high a speed can lead to disruption or even complete destruction of fine species, disruption of various cell protrusions, or breakage of algal shells, which makes it impossible to determine or systematic classification and may adversely affect the outcome. The speed and centrifugation time given in the valid standard STN 75 7711 are a compromise between the height of the risk of casting small planktonic species in the supernatant and the destruction of fine species in the sediment [129]. The standard determines the centrifugation of a volume of 10 ml of water taken for 5 minutes at 2000 rpm (at a rotor radius of 0,08 m). The formula for converting the number of revolutions at a different rotor radius can be found in the relevant standard. After centrifugation, the supernatant is discarded so that all the sediment remains in the tube. The supernatant is not poured into the sink, but into the prepared clean beaker, resp. so that it can be re-used if necessary to replenish the volume in the tube. Since water remains on the walls of the tube after pouring, it must be reattached to the sediment to prevent changes in the resulting numbers by possible dilution. The tubes are therefore placed back in the centrifuge (Fig. 149) and centrifuged briefly for 30 seconds. The resulting volume in the tube is pipetted to 0,2 ml. The supernatant must be aspirated with a pipette very carefully, only from above, in order to avoid turbulence of the sediment and possible aspiration of organisms! [128].

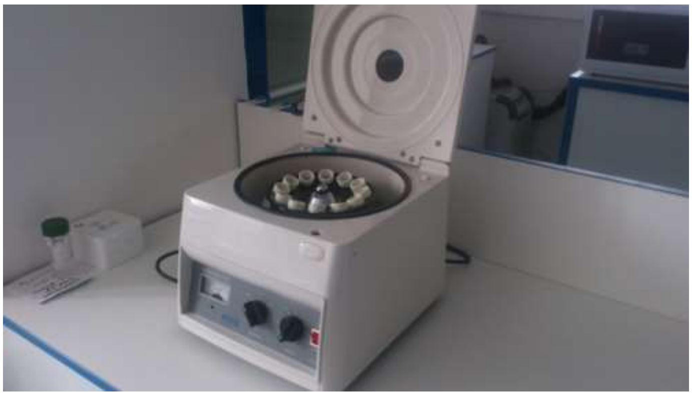


Fig. 149 Centrifuge with samples [120]

The problem of this methodology is **planktonic cyanobacteria / cyanobacteria forming an aquatic flower**. Due to the presence of gas vacuoles in the cells, they float on the water surface, respectively. in the water column and their centrifugation is therefore not possible. Even after centrifugation, they still remain at the water level in the test tube, and by pouring the supernatant we could pour them out very easily. If a visually dense aquatic flower is detected in the sample and concentration by centrifugation could cause changes in the quantity of cyanobacteria / cyanobacteria by casting, the sample must be quantified, either directly, without prior centrifugation (non-concentrated), or concentrated by filtration on a membrane filter.

Membrane filtration

Membrane filtration It does not eliminate the cyanobacterial water flower and its procedure is described in the methodology of Dr. Horeckej [132]. In this procedure, 10 ml of the sample is passed through a filter device and the phytoplankton filter is dried at room temperature. The filter is observed after the dripping of the immersion oil, which makes it clear and allows the cells to be counted. Cells are counted over the entire filter area and the total number per unit volume is calculated according to the relationship [130]:

$$Buniek\ v\ 1\ ml = \frac{a}{V} \tag{6.3}$$

where:

a - is the number of cells on the filter,
V - is the volume of filtered water.

6.12.3 Microscopic analysis

The concentrated (or non-concentrated) sample is ready for microscopic analysis after annealing to room temperature (about 20 ^{o}C). Microscopic analysis is performed at 200x magnification, if necessary greater, and counting chambers are used to quantify the organisms [128].

6.12.3.1. Counting Chambers

The counting chamber is defined by the exact dimensions of the grid, the exact volume and height. There are several types available on the market, which differ in volume, height, grid and, most importantly, accuracy. For the purposes of biological analyzes, the most commonly used chambers were Cyrus I., Cyrus II. and Bürker. The Bürker chamber is currently used in microbiological determinations and analyzes of wastewater and, due to its small volume (0,001 ml), is not suitable for the determination of biosestone, as it introduces too much error into the result. Cyrus II's chamber. has a volume of 0,005 ml and a grid divided into 2500 squares, but statistical analysis of the uncertainties of quantification showed that this volume is still too small and the result of counting on a Cyrus II chamber. too inaccurate. Therefore, only the Cyrus I counting chamber [129] should be used for the quantification of biosestone in surface and drinking water samples according to the requirements of the valid standard STN 75 7711 (Fig. 150).

The dimensions of the Cyrus I chamber are as follows:

- grid dimensions: 10 x 10 mm,

- chamber volume: 0.01 ml,
- number of squares: 1600.

Fig. 150 Chamber CYRUS I. [120]

The sample must be homogenized before transferring the sample to the counting chamber. Homogenization is a very important step and can significantly affect the quantification result, as we count only a part of the homogenized sample on the chamber and not its entire volume. Homogenization is performed either by careful but thorough mixing of the sample in the tube with a preparation needle, or by multiple slow aspirations into the pipette and draining without bubbling. By bubbling, resp. rapid hectic mixing could result in splashing of the sample and thus trapping organisms on the walls of the tube, which would reduce the number of species detected and adversely affect the result [128].

After mixing, a portion of the concentrated sample is pipetted onto a grid of cleaned Cyrus chamber and covered with a coverslip. Only original coverslips made especially for Cyrus chambers can be used, as they are sufficiently hardened to maintain the required sample volume in the chamber. Thinner slides do not maintain this volume, leaving a different sample volume on the chamber, resulting in differences in the resulting numbers. The coverslip is fastened with clamps and the excess water is forced into the side channels. Water is removed from the channels by blowing so that no moving organisms can escape into it during the analysis. The Cyrus chamber must always be cleaned at the beginning and end of the analysis with 70 % ethanol. If we clean the chamber before analysis, rinsing with distilled water is also recommended, as using a large amount of alcohol may leave some of it on the grid and cause the death of some sensitive organisms (e.g. colorless flagella, some Chrysophyceae) [128].

6.12.3.2. Counting Organisms

The calculation of organisms in drinking water sources, during its treatment, in treated water and in surface water is based on the definition of the individual [128].

The individual is a single-celled and multicellular living organism. Individuals are considered to be a single **cell** of algae, cyanobacteria, bacteria, flagella and eels, cyanobacteria and algae, **colonies up to 60 µm in diameter**, bacterial, fungal, cyanobacteria and algae fibers up **to 100 µm in length** and the **whole organism** of multicellular animals (Rotifera, Nematoda, Tardigrada, Copepoda, etc.). For colonies of large consumers, e.g. epistylis, zoothamnium and conifers of the genus Conochilus are counted as a unit for each member of the colony. Larger colonies and fibers (exceeding the specified size limits of 60 and 100 µm) are expressed as multiples thereof. The determination of such size limits is related to the dimensions of the grid taking into account the average particle size separable by conventional water treatment and can be easily estimated by comparison with the square length of the counting grid. 60 µm (colony or cenobio diameter corresponding to one individual) corresponds to the rounded value of half the side length of the small square of the counting grid (Fig. 150), 100 µm (fiber length corresponding to one individual) corresponds approximately to the length of one side of the small square of the counting grid (page length is 125 µm - Fig. 151) [130].

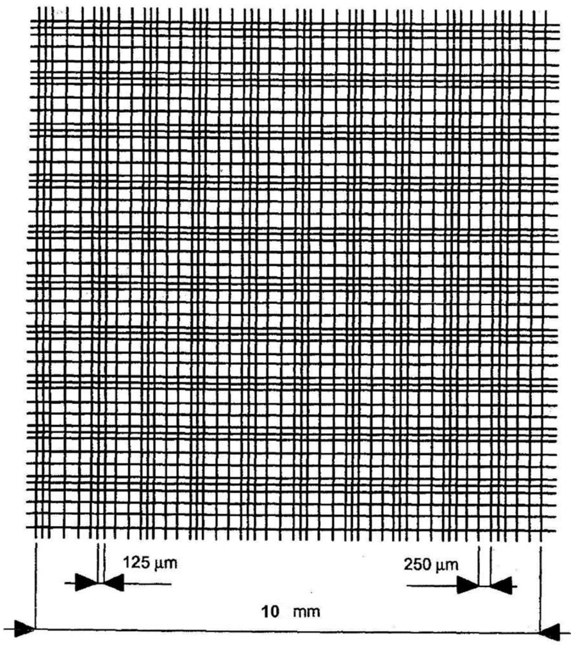


Fig. 151 Grating of Cyrus I. counting chamber, size 1 square 250 x 250 µm., Size of the whole grid 10 x 10 mm [129]

For the purposes of water quality control **in natural swimming** pools according to the Regulation of the Government of the Slovak Republic No. 252/2006 Coll. on the details of the operation of swimming pools and details on the requirements for the quality of swimming pools, bathing water and its control, the quantification of **cyanobacteria / cyanobacteria present in cells per ml** is required.

The expression of the number of organisms in the sample by number of cells per ml should be considered depending on the requirements of the legislation and the purpose of the analysis. The number of cells more precisely defines the total volume of organisms in a given volume and is of great importance in determining the volume of biomass. For example, when comparing the quantity of biostones in raw treated water and treated water, each colony or fiber must also be expressed in terms of cell number, as colony breakdown could result in colony breakdown due to the water treatment process [128].

The standard STN 75 7714 for the determination of biosestone in surface waters is currently underway, according to which it will be possible to express the number of organisms in several ways [133].

Individuals are counted under a microscope according to the density of the sample either on the entire area of the grid of the chamber or on its part. In little-lived raw water samples, treated water samples are counted and identified as organisms throughout the cell; in other cases, when the number of organisms is larger, individuals are counted in individual fields or bands. When counting organisms in the strips or squares of the chamber, the rule is that only organisms that are entirely inside the strip or field and organisms that touch the upper and right edges of the grid (or sides of the square or strip) are counted. Organs that touch the lower and left sides are not counted to avoid re-counting an individual in the next contiguous zone. First, motile organisms and those that are subject to rapid destruction by prolonged stay in unsuitable environments (e.g. Chrysophyceae and Cryptophyceae) are counted. The smallest errors in the counting of moving organisms that pass between the individual bands are made if they are counted as quickly as possible and at a lower magnification (when there is a larger number of bands in the field of view (3 - 4)). Of course, the magnification must be large enough for the counted organisms to be able to be classified correctly! When moving slowly in the belt and gradually recalculating one square after another, it is usually not possible to count the same moving individual several times!

The choice of the calculated area is governed by the density of organisms in the sample. If only a part of the chamber is counted, a larger number of strips (or fields) will ensure a more representative selection and a more accurate result. The choice of bands and squares is random, STN 75 7711 recommends determining the biostone from one middle and two edge bands [129]. For more revitalized samples, it is recommended to determine the species composition first (qualitative analysis) and then quantify them.

6.12.4 Determination of the Number of Individuals per 1 ml

The number of individuals x in 1 ml of the sample is determined according to the formula:

$$x = \frac{a\ .\ K}{n\ .z\ .V} \quad \text{[ks/1 ml]} \tag{6.4}$$

where:

- *a* - is the number of individuals in *n* squares,
- *n* - is the number of examined squares,
- *z* - is the concentration of the sample,
- *K* - is the total number of squares in the chamber,
- *V* - is the volume of the chamber in ml.

For the chamber Cyrus I. [128]**:**

<u>When concentrating the sample from 10 ml to a volume of **0,1 ml**</u> (z = 100, K = 1600, V = 0,01) has the formula shape:

$$x = \frac{a\ .\ 1600}{n\ .\ 100\ .\ 0{,}01}\ z\ toho\ x = 1600\ .\ a\ /\ n \tag{6.5}$$

<u>When concentrating the sample from 10 ml to a volume of **0,2 ml**</u> (z = 50, K = 1600, V = 0,01)

has the formula shape:

$$x = \frac{a\ .\ 1600}{n\ .\ 50\ .\ 0{,}01}\ z\ toho\ x = 3200\ .\ a/n \tag{6.6}$$

<u>For non-thickened sample</u> (z = 1, K = 1600, V = 0,01) has the formula shape:

$$x = \frac{a\ .\ 1600}{n\ .\ 1\ .\ 0{,}01}\ z\ toho\ x = 160\ 000\ .\ a\ /n \tag{6.7}$$

Tab. 22 shows the conversions of organisms to the various examined areas of the chamber, derived from the mentioned formulas.

Tab. 22

Conversion of organisms x to 1 ml when concentrating the sample from 10 ml to 0,1 ml and 0,2 ml, when counting the different parts of the grid of the Cyrus I counting chamber [129]

Area examined	**Number of squares [n]**	**Dimension of the area examined**	**Number of organisms *x* when the sample is thickened from 10 ml**			
			per volume of 0,2 ml		**per volume of 0,1 ml**	
			to the chamber	**resulting conversion to 1ml**	**to the chamber**	**resulting conversion to 1 ml**
1 square	1	250 µm x 250 µm	x 1600	3 200 a	x 1600	1 600 a
1 belt	40	250 µm x 10 mm	x 40	80 a	x 40	40 a
2 strips	80	500 µm x 10 mm	x 20	40 a	x 20	20 a
4 strips	160	1 mm x 10 mm	x 10	20 a	x 10	10 a
8 strips	320	2 mm x 10 mm	x 5	10 a	x 5	5 a
10 strips	400	2500 µm x 10 mm	x 4	8 a	x 4	4 a
The whole chamber	1600	10 mm x 10 mm	x 1	2 a	x 1	1 a

Depending on the nature of the sample, three sample preparation procedures can be used [128]:

1. If the sample consists predominantly of fibrous cyanobacteria that do not form opaque clusters (e.g. Pseudanabaena, Anabaena) or in the presence of smaller colonies (up to 50 cells per colony), we can count them without disintegration. After homogenization, the sample is applied to a CYRUS I chamber, from which the final number of individuals and cells is determined using a microscope. First, 10 ml of the mixed sample is taken into a centrifuge tube and centrifuged for 5 minutes in a non-braked rotor centrifuge. The rotor radius is 0,08 m and centrifuges at 1 900 rpm. If the rotor radius is different, it is calculated according to the formula:

$$n_2 = \sqrt{\frac{n_1^2\ .\ r_1}{r_1}} = \sqrt{\frac{3{,}2\ .\ 10^5}{r_2}}, \tag{6.8}$$

where:

n - is the number of rotor revolutions / min,

r - rotor radius in m,
index 1 - expression of speed at rotor radius 0,08 m,
index 2 - expression of the number of rotor revolutions / min at a different rotor radius.

2. If the sample consists predominantly of fibrous cyanobacteria, the sample shall be: Lugol's solution is added for disintegration. The minimum volume of solution added to the sample is 10 ml, which gives the sample a dark brown color. If agglomerates flos-aque predominate in the sample, a minimum sample volume of 400 ml is required. The sample is then mixed to disintegrate the clumps and the cyanobacteria on the CYRUS I chamber are counted from the disintegrated sample.

3. If the sample consists of microcystis or Anabaena colonies with twisted fibers, the sample must be disintegrated into substantially smaller colonies. The disintegration efficiency may decrease depending on the physicochemical properties of the colony mucus and also depends on the nature of the sample. The homogenized sample is poured in a volume of 5 ml into a more suitable tube and a solution of potassium hydroxide (0,1 - 0,2 ml) is added depending on the cyanobacterial concentration of the sample. The sample is then pipetted in rapidly with an automatic pipette 10 times, drained and left to stand for a minimum of 2 minutes at room temperature. The tip of the 2 mm diameter pipette is pressed as close to the bottom of the tube as possible during extrusion. If, during the observation, there are units in the sample with a cell number greater than 50, the procedure is repeated with the addition of KOH.

The disintegration efficiency depends on the nature of the sample examined.

"In the case of filamentous cyanobacteria (Aphanizomenon, Planktothrix, Pseudanabaena), the number of cells is determined on the basis of fiber length. The corresponding fiber length per cell is 5 µm".

$$A_i = \sum_{i=1}^{n} = \frac{p \,.\, P_k \,.\, V_z \,.\, (V_d + V_{KOH})}{P_p \,.\, V_p \,.\, V_k \,.\, V_d} \text{ [ks/1 ml]} \qquad (6.9)$$

where:

A_i - number of cells of all cyanobacterial taxa (cells in 1 ml),
n - total number of cyanobacterial taxa counted,
p - number of cyanobacterial cells in the counted part of the chamber,
P_p - calculated area of the chamber in mm^2, or expressed as the number of strips or squares of the chamber,
P_k - total area of the chamber in mm^2, (40 strips or 1,600 squares),
V_d - volume of the sample for disintegration in ml,
V_{KOH} - volume of added reagent in ml (KOH, Lugol's solution),
V_p - volume of sample used for concentration in ml,
V_z - volume of the concentrated sample in ml (if the sample is not concentrated Vz = 1 ml),
V_k - volume of the CYRUS I chamber in ml (0,01 ml).

6.12.4.1. Disruptive Effects of the Determination

Several sources of errors and uncertainties are involved in the whole analysis, which are related to homogenization of the sample before concentration, elimination of organisms during centrifugation (destruction of fine species by overpressure and fusion of organisms with supernatant after centrifugation), homogenization of concentrated sample before microscopic analysis of course a human factor in the actual counting and systematic classification of individuals. All these factors must be taken into account when calculating the uncertainties of the determination. Most importantly, however, the sample preparation and analysis itself must follow the requirements of the relevant standards. Only in this way will it be possible to avoid unnecessarily introducing errors into the quantification result and to achieve the correct result. [110]

6.13 Technical Equipment for The Revitalization of Standing Waters

For the revitalization of stagnant waters, the authors of the monograph designed and constructed two facilities, which were implemented at the Department of Environmental Engineering, Faculty of Mechanical Engineering, Technical University of Košice and in accordance with the objectives of the ITMS project: (26220220028) "***Implementation and modification of technology to reduce the occurrence of sieveds in stagnant waters***". Funding for both facilities was from this project. [110]

The revitalization of stagnant waters can be divided into two phases. The primary phase consists of a float electrolytic device. The secondary phase consists of a catamaran device, where the device collects minor impurities from the surface of the water, especially the blown-out sieved and algae after the action of the electrolyte device (primary phase). [110]

6.13.1 Float Equipment for Revitalization

At the Department of Environmental Engineering, two variants of float equipment for the revitalization of stagnant waters have been developed. The first variant is a float device with a star electrode connected to a diode rectifier and the second variant is a float device with a star electrode connected to a wind dynamo.

The technical solutions of the standing water revitalization plant relate to the electrolytic method of disposing of cyanobacteria and algae.

6.13.1.1. A Float Device with a Star Electrode Connected to a Diode Rectifier

The first variant of the float device consists of a float made of circular polypropylene copolymer (PPC), a rib, a star electrode and a diode rectifier.

The Principle of the Device

In the middle of the carrier float, electrolysis takes place below the water surface, and in clear force circles, the formed oxygen and hydrogen bubbles carry paralyzed or neutralized cyanobacteria to the surface of the water surface by electro flotation [120].

Carrying Float

The carrier float consists of four equal parts (Fig. 153). The float is made of polypropylene copolymer (PPC) to be as light as possible, resistant to external influences and at the same time able to float on water. The diameter of this support part is D = 3,8 m, which represents a hollow disk with a width of 700 mm and a height of 800 mm. The diagram of the carrier float is shown in the following Fig. 152. A real view of the carrier float of the device is shown in the following Fig. 153.

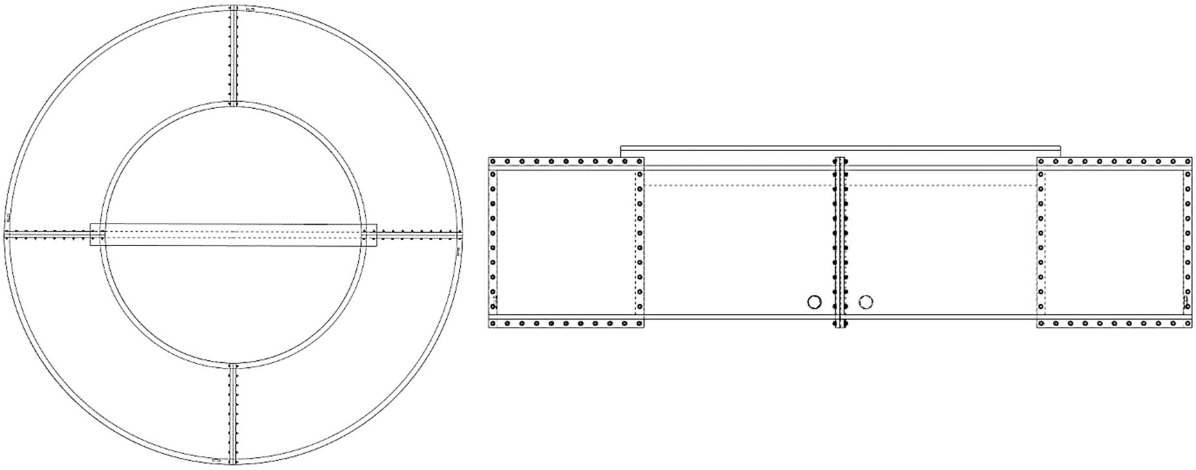


Fig. 152 Schematic of a carrier float

Fig. 153 Real view of the hollow cylinder-shaped support float [120]

The float consists of four equal parts, which are connected by screws around the entire circumference of the joint (Fig. 154). Connecting screws M14 x 80 in the number of 112 pieces connect the individual parts of the float into one unit.

Fig. 154 Real view of connecting screws [120]

Rib

The rib is the inner part of the float, which is attached along the inner hole of the float and serves to fasten the star electrode, which is immersed in water. The diagram of the inner rib is shown in the following Fig. 155. [120]

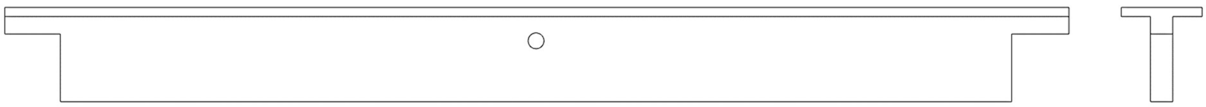


Fig. 155 Diagram of the inner rib

A real view of the inner rib is shown in the following Fig. 156.

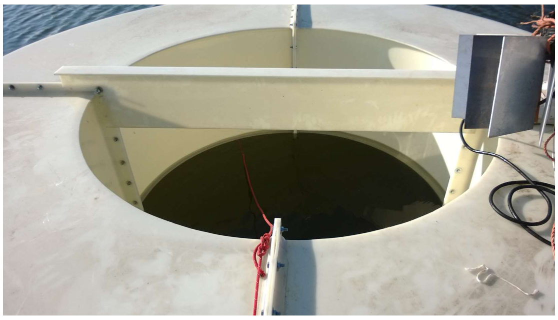


Fig. 156 Rib

The rib has several functions [120]:

- is a suspension module of a star electrode placed in water,
- is the base of the wind dynamo stand,
- is a suspension module for anchoring a float on a water surface.

The rib as well as the carrier float are made of polypropylene material. The use of polypropylene for the construction of a float device has several characteristic advantages [120]:

- high abrasion resistance,
- high mechanical load capacity,
- good damping properties,
- high flexibility,
- wide hardness range,
- high tear resistance,
- high notched toughness,
- very suitable for dynamic stresses,
- good resistance to mineral oils, greases, fuels,
- aging resistance,
- color fastness,
- resistance to hydrolysis,

- without the presence of plasticizers,
- different ways possible.

Star electrode

The electrodes are interconnected in the shape of a star and are powered by a direct source of electricity. In this way, electrocoagulation occurs, where the agglomerated particles are carried to the surface [134]. The following (Fig. 157) shows the diagram of the star electrode.

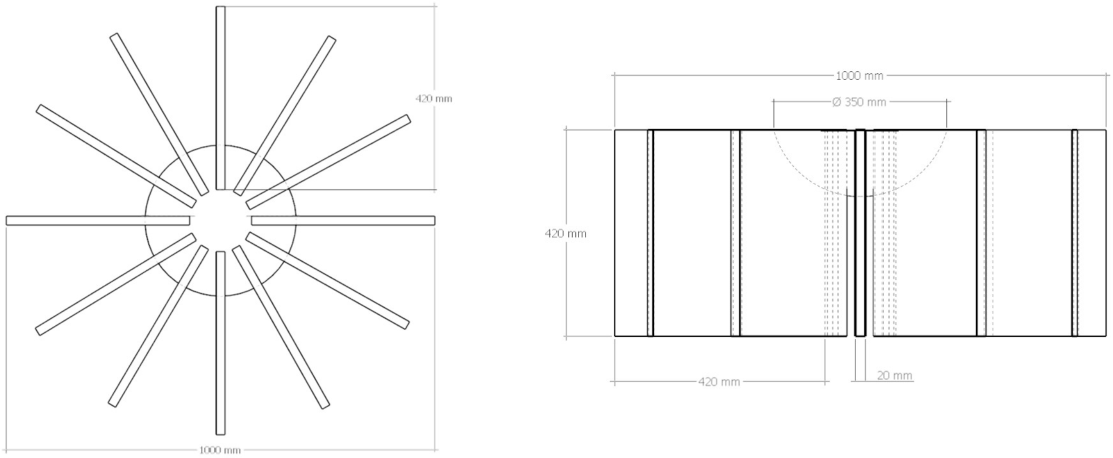


Fig. 157 Star electrode diagram

In the following Fig. 158 is a realistic view of the star electrode as well as the electrode array.

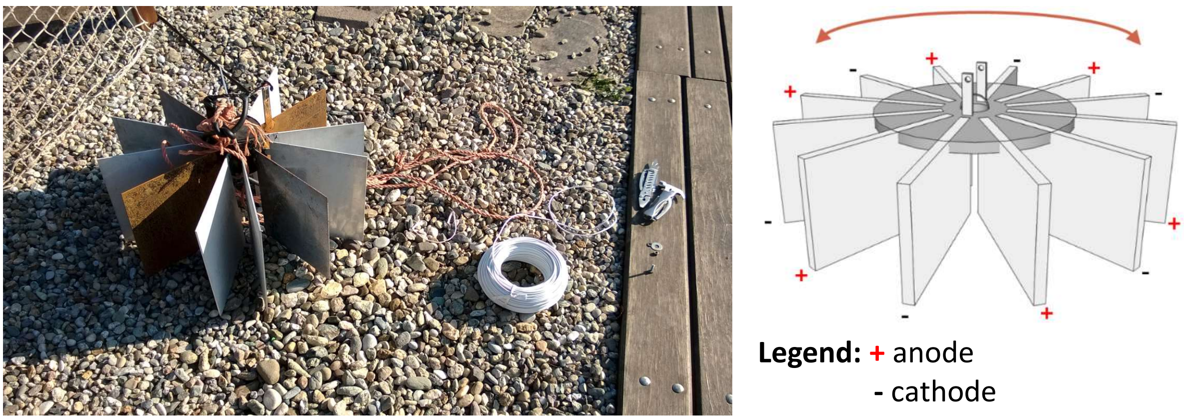


Fig. 158 Real view of the star electrode and electrode arrays

The largest star electrode with a diameter of 1000 mm (Fig. 159 a) is used for the proposed device, which is used for large water areas, the middle star electrode with a diameter of 500 mm (Fig. 159 b) is intended for medium and small water areas, tanks, lakes as well as ponds. The smallest star electrode with a diameter of 250 mm (Fig. 159 c) was developed for laboratory purposes at the Department of Process and Environmental Engineering. Star electrodes consist of iron and aluminum electrodes [135]. A real view of the individual types of star electrodes are shown in Fig. 160.

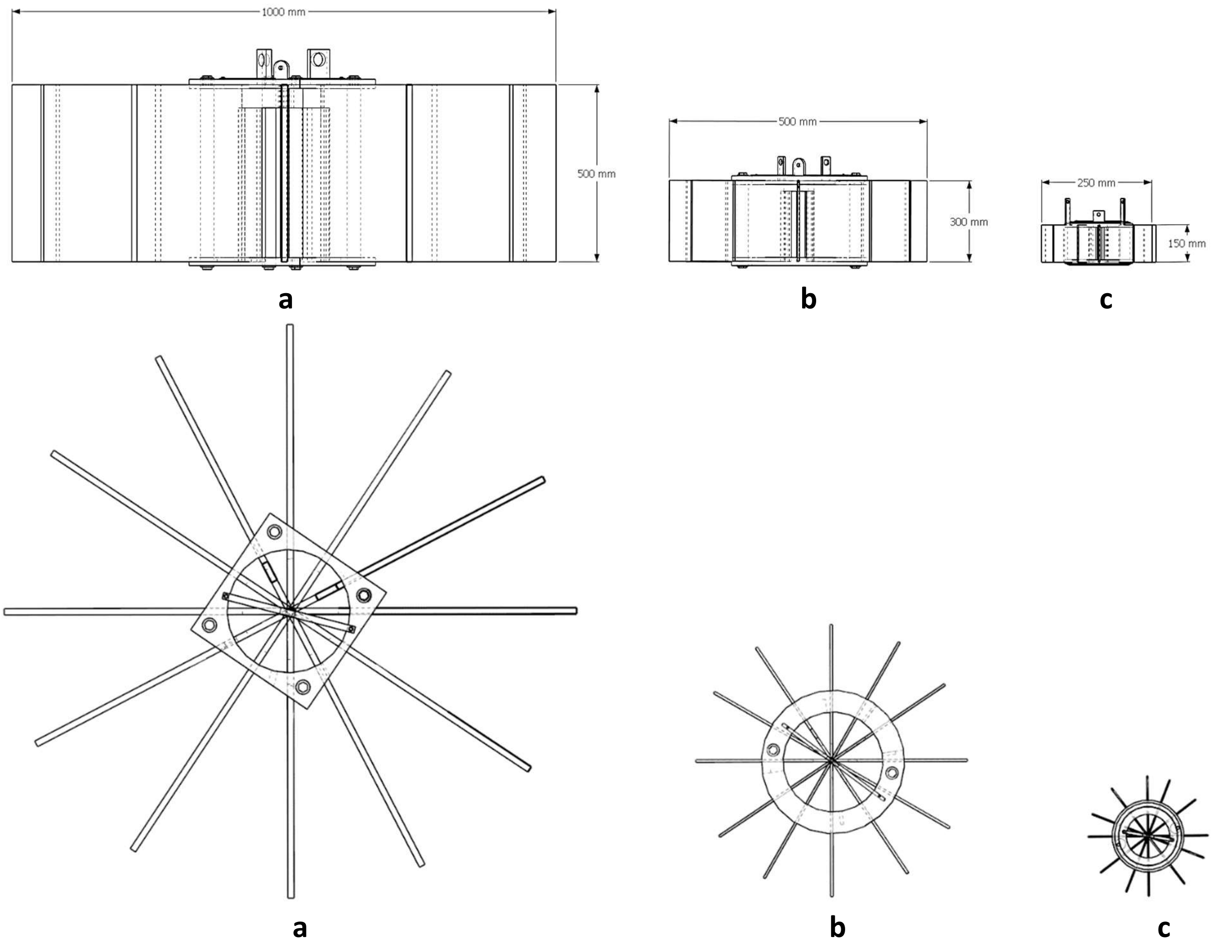


Fig. 159 Scheme of star electrodes

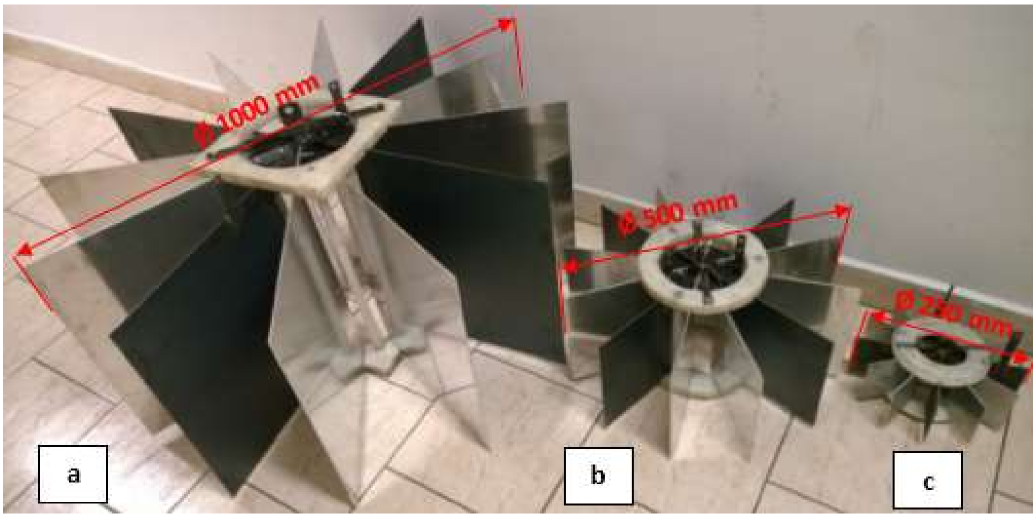


Fig. 160 Real view of star electrode types [136]

Diode rectifier FOR WPL 200

ForWPL (Water Purification Lake) (Fig. 161) is a classic diode rectifier that serves as a source of direct current with step regulation up to 200 A for water purification in lakes. In terms of climatic design, it corresponds to class N2 or N3 according to STN 03 8805, i.e. in areas with a temperate climate.

Before switching the power supply to the POWER position, it is necessary to test the power supply in the TEST position so that the output terminals come under voltage and start cooling. The device must be constructed in such a way that the airflow provided by the indoor fans is not impaired. The WPL 200 power supply operates at a mains voltage of 400 V with a maximum tolerance of 10 % of the nominal value. The voltmeter shows the current value of the voltage at the output terminals of the source and the ammeter shows the value of the current flowing to the output terminals. [120]

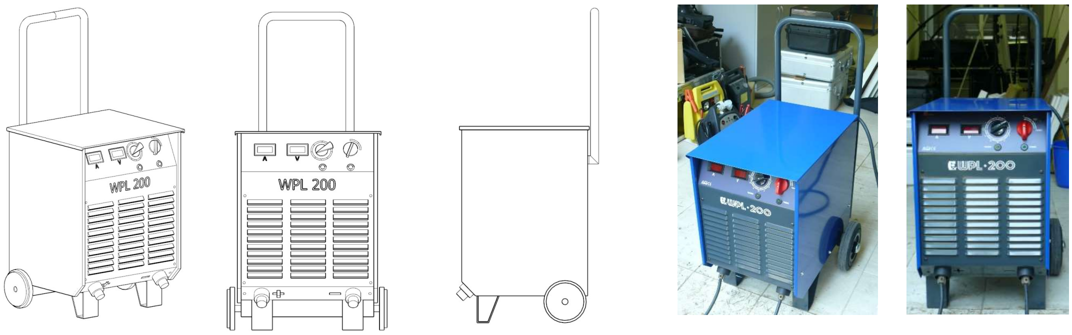


Fig. 161 Diode rectifier WPL 200 [120]

In the following Tab. 23 shows the technical parameters of the diode rectifier.

Tab. 23
Technical parameters of the WPL 200 diode rectifier [120]

Source type	Unit	For WPL 200
Supply voltage	V	400
Number of phases		3
Frequency	Hz	50/60
Rated current	A	13
Rated power input	kA	9
Insurance	A	20
Power cable	mm²	4 x 2.5
Setting range	A	10 - 200
Voltage is empty	V	15 - 40
Coverage		IP23
Isolation class		F
Cooling		AF
Ambient temperature	°C	0 - 40
Length	mm	570
Width	mm	520
Height	mm	930
Weight	kg	80

Power cables

To connect the star electrode to the diode rectifier, power cables of the CGZ 25 type (Fig. 162) with a length of 5 m were used, which are used to transmit the electric current. In the following Tab. 24 shows the individual components of the float device with a star electrode, connected to a diode rectifier. [120]

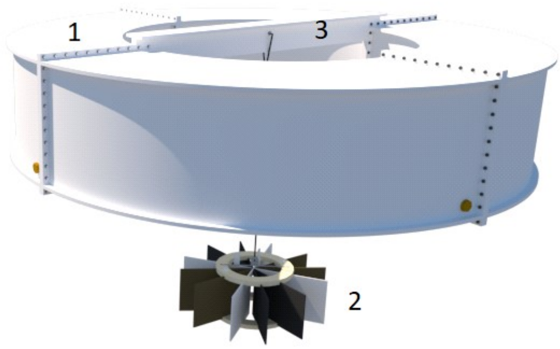
Fig. 162 Power cables type CGZ 25

Tab. 24
Components of the star electrode float device connected to the diode rectifier

Serial Number	Construction part	Material	Count [pcs]	Weight of one [pcs]	Total weight [kg]
1	Carrying float	Polypropylene	4	75	300
2	Rib	Polypropylene	1	10	10
3	Star electrode	Iron, aluminium	1	20	20
Total weight of the device					**330**

Note: * star electrode with a diameter of 500 mm
The diode rectifier is not counted as it is located outside the float device.

The 3D views of a float device with a star electrode are shown in Fig. 163 to Fig. 166.



Legend: 1 - carrier float,
2 - rib,
3 - star electrode.

Fig. 163 3D graphical representation of a float device with a star electrode

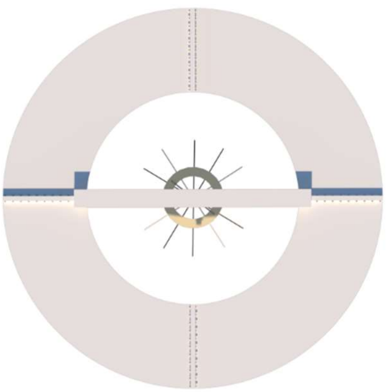


Fig. 164 3D top view of a float device with a star electrode

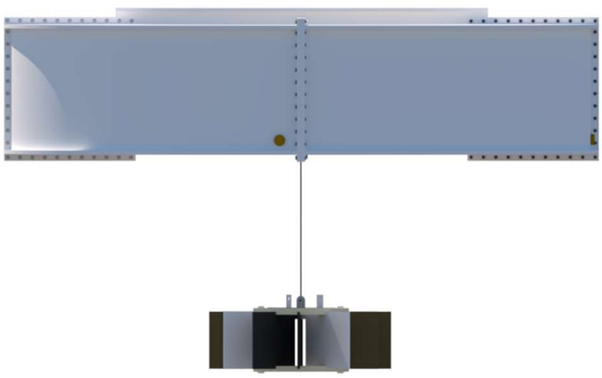


Fig. 165 3D side view of a float device with a star electrode

Connection of technical equipment

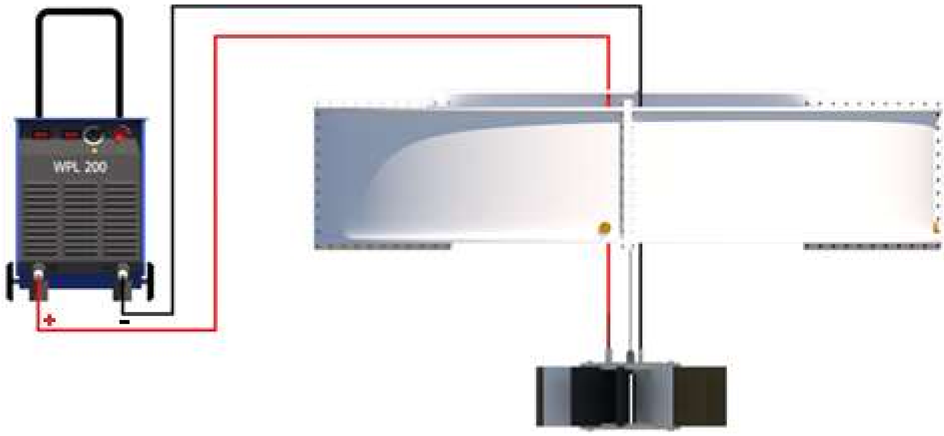


Fig. 166 Schematic connection of the float device

Float device with a star electrode connected to a wind dynamo

The second variant of the float device also consists of a float made of circular polypropylene, ribs, a star electrode with the difference of an added wind dynamo with a stand for the use of a renewable energy source. The dimensions of the float are identical to the first variant. [120]

Wind dynamo

The AIR 40 Breeze device (Tab. 25), which converts wind energy into electricity via converters. It consists of rotor blades, rotor itself, gears, generator and control components. A real view of the wind dynamo is shown in Fig. 168.

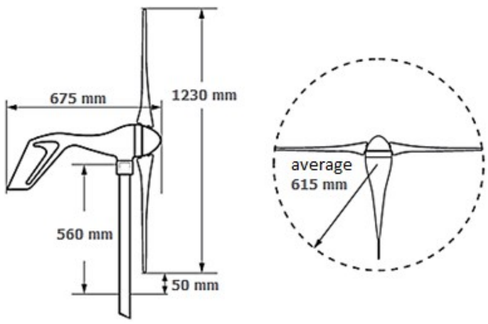


Fig. 167 Scheme of wind turbine revitalization plant [120]

Fig. 168 Real view of the AIR BREEZE 40 wind dynamo

The wind dynamo principle is based on the principle of converting the kinetic energy of the wind through the turbine blades into mechanical energy, which is transmitted to the generator and converted into electrical energy (Fig. 167). The AIR 40 is powerful and precisely designed to transfer wind energy at low wind speeds than any other type in its class. The basis is an internal controller controlled by a microprocessor with monitoring of the highest power, which increases efficiency and optimal energy performance. Three composite blades bring increased reliability, durability as well as reduced noise. The last necessary component is a neodymium alternator, which ensures greater use of energy supply without the need for maintenance. The ideal combination is the use of a wind turbine (Tab. 25) and solar panels to provide regular energy in all weathers. [120]

Tab. 25
Technical parameters of the AIR BREEZE 40 wind turbine

Model	AIR 40
Weight	6 kg
Rotor diameter	1,22 m
Kilowatt hour/month	38 kWh/month at 5,4 m/s
Max. wind speed	49,2 m/s
Certificate	CSA 195-4979, CE
Usability temperature	-10 °C to 40 °C
Rated power	160 W at 12,5 m/s
Stand pipe diameter	48 mm
Tension	12V and 24V

Wind dynamo stand

Three-point stand made of stainless steel with adjustable height for wind dynamo Air 40 Breeze. In the following Tab. 26 shows the individual components of the float device with a star electrode connected to a diode rectifier. [120]

Tab. 26
Floating device with a star electrode connected to a wind dynamo

Serial number	**Construction part**	**Material**	**Count [ks]**	**Weight one [ks]**	**Total weight [kg]**
1	Supporting float	Polypropylene	4	75	300
2	Rib	Polypropylene	1	10	10
3	Wind dynamo	Plastic, iron, aluminum, electro	1	6	6
4	Star electrode	Iron, aluminium	1	20	20
5	Wind dynamo stand	Stainless steel	1	40	40
6	Distribution box	Plastic, electrical parts	1	2	2
7	Control unit	Plastic, electrical parts	1	1	1
8	Battery	Lead/ gel	2	20	40
9	Cables	Copper, rubber	6	1	6
Total weight of the equipment					**425**

In the following Fig. 169 to Fig. 171 show 3D views of a float device with a wind dynamo.

Fig. 169 3D view of a float device with a wind dynamo [120]

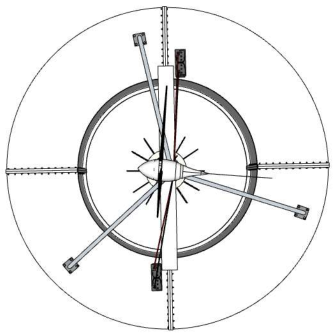
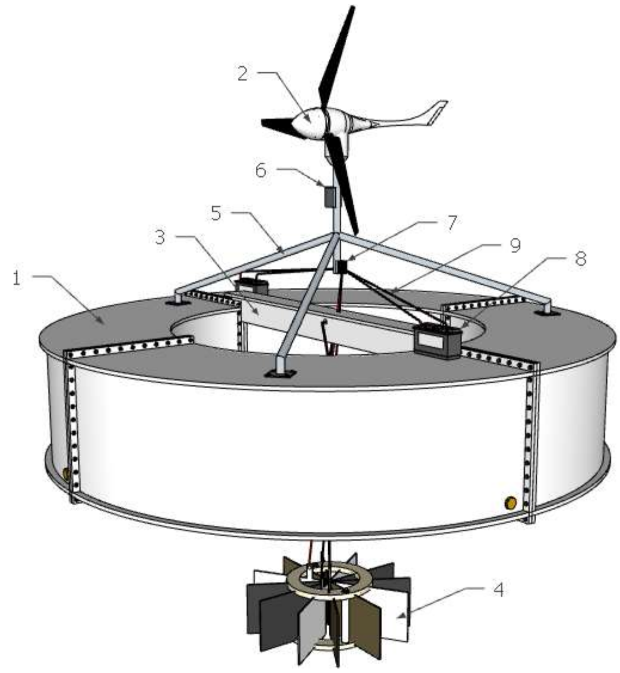


Fig. 170 3D view of a float device with a wind dynamo [120]



Legend: 1 - carrying float,
2 - wind dynamo,
3 - rib,
4 - star electrode
5 - wind dynamo stand,
6 - distribution box,
7 - control unit,
8 - battery,
9 - cable.

Fig. 171 3D view of a float device with a wind dynamo [120]

The method of disposal of cyanobacteria in still waters and the equipment for its implementation is currently protected by patents and utility models, as well as by the PCT application.

6.13.2 Measuring the Range of Electrolytic Equipment

Description of the experiment

Measurements of the range of electrolytic equipment were carried out on Lake Čaňa 20 km from Košice. The following Fig. 172 shows the location of the experiment with the designation of electrolyte equipment and stationary camera.

Fig. 172 Map of the site of the electrolyte experiment [137]

After moving the float device to the site of the experiment, the device was anchored, due to movement. The float was anchored to a rope 6 m long. Subsequently, a star electrode was inserted into the hole of the float device and electrolysis was triggered (Fig. 173).

Fig. 173 Map of the site of the electrolyte experiment

The float device and its position were recorded by a stationary camera and continuously shot between 10.10.2021 12:41:21 until 20.11.2021 18:00:00. From the continuous record, sequences Fig. 174 were randomly selected.

Background image

Scale: $\frac{300\ cm}{2\ cm}$ = 150:1 U = up, D = down, L = left, R = right

U: 16 mm, D: 67 mm, L: 47 mm, R: 41 mm

Fig. 174 Background image from experimental measurement

On the basis of the project description, the implementation and verification of the technology for the disposal of sieved sieved in stagnant waters was intended to verify the size of the area covered by the floating installation in external weather conditions [137].

Evaluation of the experiment

The circumcision of Fig. 174 is considered a projection of the image taken by the camera on the same scale. The movement of the float to the left - to the right and from the camera and to the camera is shown on the primlet at the appropriate scale.

While the left-right movement at the depth of field of the camera on the image area detects only minimal distortion, the movement from and to the camera depends on the projection of the angle that the camera level and water level. In Fig. 175 shows a method of monitoring and capturing individual images on a scale [137].

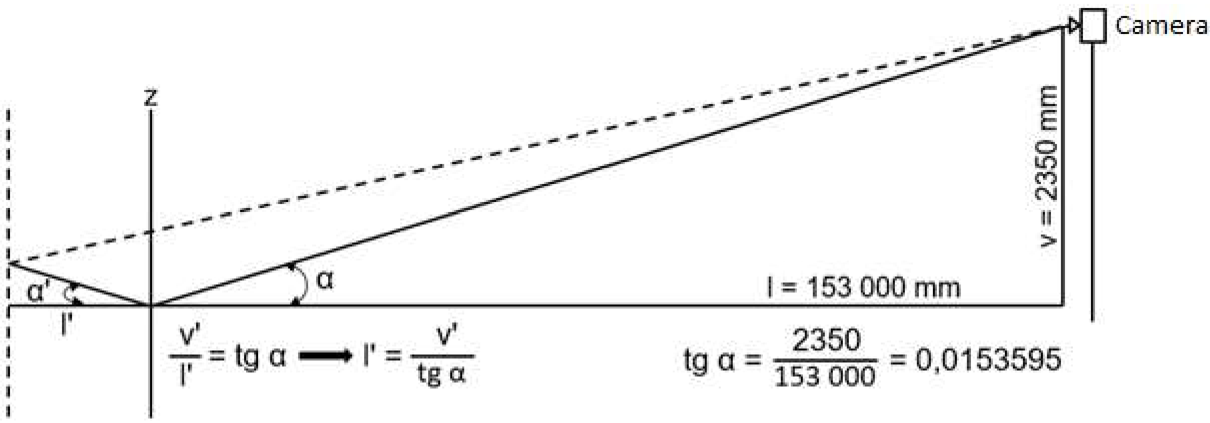


Fig. 175 Grafic representation of the evaluation of the experiment [137]

The angle **α** was calculated according to the actual data, i.e. the height of the camera above the level **v = 2350 mm** and its distance from the float **153 m,** i.e. the movement of the float away from the camera in the picture, we record as a movement up and vice versa.

l = 153000 mm **tg α =** $\frac{\mathbf{2350}}{\mathbf{153000}}$ **= 0,0153595**

The movement of the float away from the camera in the image is recorded as a movement upwards and vice versa. The actual length of movement is calculated from distortion at an angle of **α**.

$$x = \sqrt{s^2 - h^2}$$
$$x = \sqrt{6^2 - 4{,}24^2}$$
$$x = \sqrt{36 - 17{,}9776}$$
$$x = \sqrt{18{,}00224}$$
$$x = 4{,}2452\ m$$

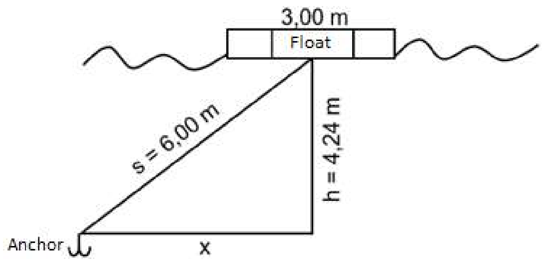


Fig. 176 Display of the projection of the reference area [137]

The predicted possible movement of the float, if we consider the anchor to be sufficiently stationary, it is clear that the float may leave a circular motion of radius x according to the Pythagorean sentence (Fig. 176). Thus, the float will occupy an area with a maximum diameter of **4,245.20 mm.**

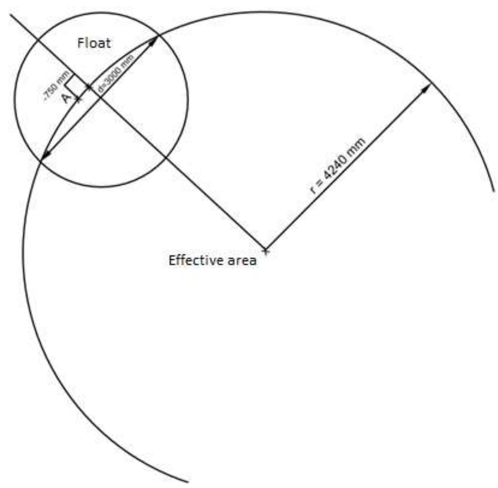


Fig. 177 Float movement to the left of the original position [137]

In Fig. 177 shows the scale movement of the float to the left of the original position (Fig. 178 12.11.2021 21:55:51). Point A indicates a movement of 750 mm to the left (minus sign). Similarly, it is possible to record points when the float moves from the basic position of the float towards and to the camera.

Fig. 178 Basic image from experimental measurement

Evaluation of the experiment

In conclusion, with prevailing winds on the water surface, the area directly above the electrodes is quite small, bounded in this experiment on an area of about **1 m².**

It is clear that in the long-term use of the above-mentioned device it is not possible to exclude the opposite directions of wind and thus assume its movement over the entire effective area with a diameter of: **8490,4 mm.**

6.13.3 Verification of Technical Equipment in Practice

The Department of Chemical and Environmental Analysis for the education of students and also for the purposes of environmental analysis was carried out at the Department of Environmental Engineering (DEE), Faculty of Mechanical Engineering (FME), Technical University of Košice (TUKE). In the following Fig. 179 shows the listed laboratory.



Fig. 179 Laboratórium chemických a environmentálnych analýz na DEE, FME, TU of Košice [138]

Description of the pilot experiment

As part of scientific research activities at DEE, FME, Technical University of Košice, a pilot experiment was carried out using the electroflotation method. A water sample with a volume of 8 l was taken from the gravel lake Čaňa (Fig. 180) on 14 July 2021 at 9:00 the largest occurrence of a water flower on the water surface. The mixed water sample had a characteristic vegetation coloration (Fig. 181 a)).

Fig. 180 View of the Čaňa gravel pit (20 km from Košice) [110]

Laboratory experiments of the influence of electrolysis on microscopic life in water were carried out at a small electrolytic plant at DEE, FME, TU of Košice, where the electro flotation process was visually monitored on a water sample from the Čaňa gravel pit.

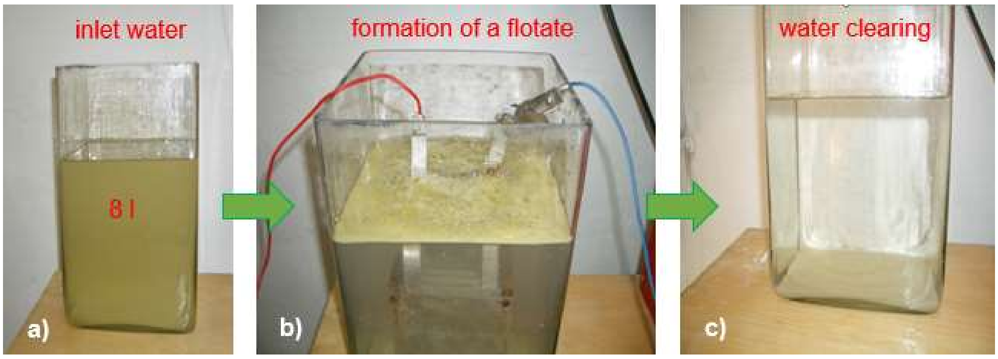


Fig. 181 Laboratory experiment [139]

Water and flotation samples at the outlet were analysed in the accredited Ekolab Košice laboratory and on the universal emission spectrometer with inductive bound plasma - ICPE - 9000 (Fig. 182).

Fig. 182 Plasma Analyser ICPE-9000

A sample of water (50 l) from the water area košice City Part (CP) - Above the lake (Fig. 183) was used to carry out the experimental disposal of sieveds and algae. The sampling was carried out on 21.7.2021 at 9:15 AM at the time of the maximum exceedance of the limit value of the number of siemen and algae cells in a given month. The mixed sample from the stencil had a significant vegetation colouring after being poured into the electrolysis container.

Fig. 183 Košice City Part - Nad Jazerom

In order to carry out electrolysis itself in laboratory conditions, it was necessary to:

- power source,
- jar,
- power cables,
- star electrode with a diameter of 250 mm,
- sample taken (min. 50 l of contaminated water) (Fig. 186 (a)).

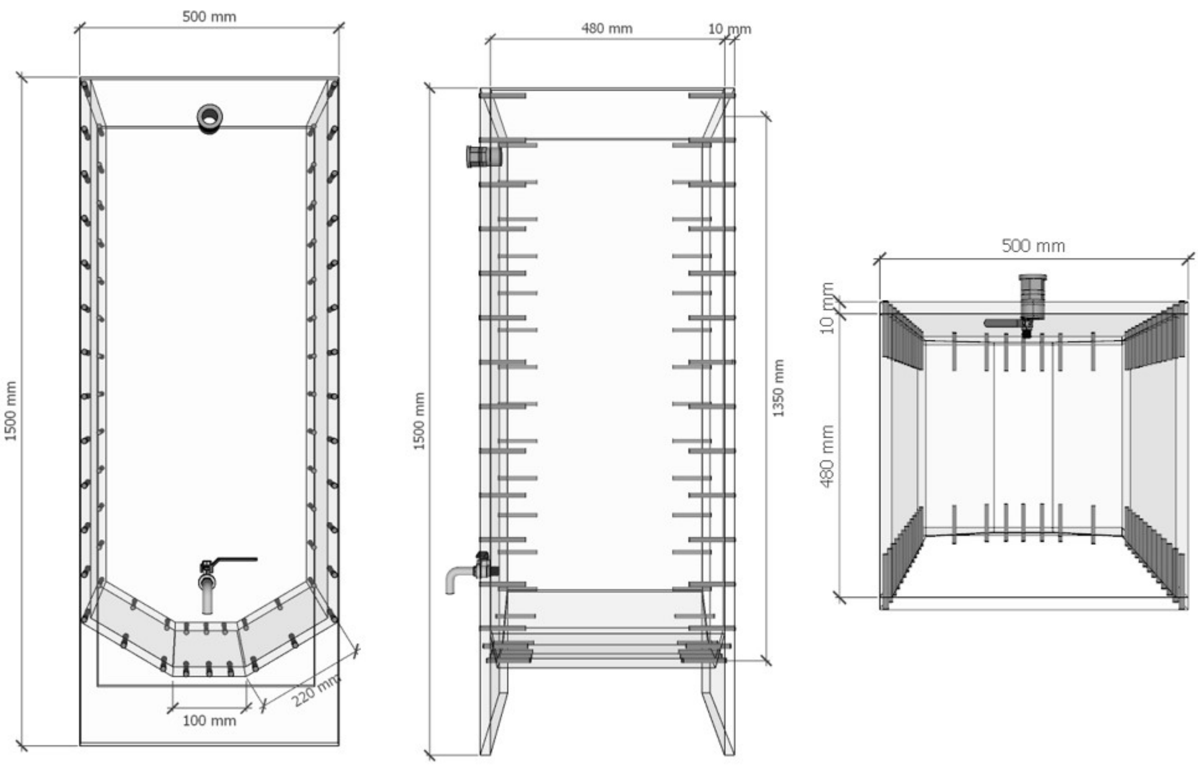


Fig. 184 Container diagram for experimental purposes [110]

A real view of the vessel for experimental purposes as well as for screwing the vessel is shown in Fig. 185 below.

Fig. 185 A real view of the container as well as screwing [110]

6.13.3.1. Experiment in the interior

By pouring water into the container and connecting the power cables to the star electrode, the current was transferred to the water surface. The electrophlolotation process was monitored for 15 minutes, 1 hour, 2 hours up to 5 hours at a voltage of 12,5 V. The electrophlolotation method effect was already present after 10 minutes by the formation of flotation foam (Fig. 186 (b)) at the sample level.

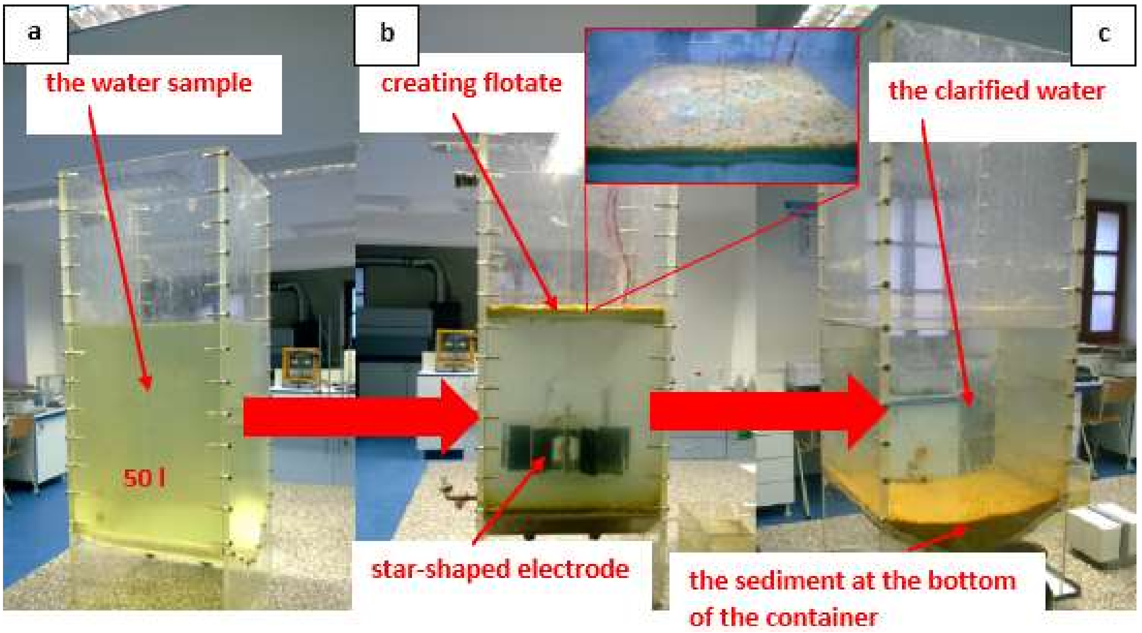


Fig. 186 Formation and sedimentation of the flotation of the sample examined [110]

Another time course caused an increase in the thickness of the flotation, thereby clearing the water and losing vegetation coloration. The created flotation was taken by hand and analysed in the laboratory of DEE, FME, TU of Košice under the supervision of an expert from the Regional Public Health Office based in Košice.

A view of the small electrodes before and after the course of electrolysis is shown in Fig. 187.

before **after**

Fig. 187 Smallest star electrode before and after electro flotation applications in the laboratory [110]

The remaining flotation, which could not be removed, was sedimented at the bottom of the container, where it no longer poses any serious biological hazard. The water remained clear after the flotate sedimentation (Fig. 186 (c)).

6.13.3.2. Experiment outdoors

Within the application of the revitalization facility for the elimination of sielos in water reservoirs, an experiment was carried out on the recreation area of the City Part - Nad Jazerom Košice (Fig. 188).

Fig. 188 City Part - Nad Jazerom Košice

The Lake reservoir does not belong to the list of water bodies declared suitable for bathing by the Regional Environmental Office based in Košice due to the fluctuating water quality. They are indicators of cyanobacteria with the ability to form a water flower and chlorophyll. By building a natural swimming pool on the water surface, which is operated by the Ministry of Education Nad Jazerm Košice, it can be put into operation by decision of the RUVZ in Košice in case of satisfactory water quality before the beginning of the summer tourist season. Water quality control of the natural swimming pool is carried out by the operator in cooperation with the Regional Public Health Office based in Košice. At the beginning of the season, the quality of the water is suitable for swimming, but during the season it fluctuates due to the overpopulation of cyanobacteria with the ability to form a water flower. [110]

The electro flotation method was applied to the water reservoir Lake - CP Nad Jazerom in Košice within the technical and economic possibilities. The experiment was carried out during the summer tourist season (from June to September) in 2020 and 2021 to reduce the occurrence of siemuths for the purpose of recreational use of the water area. In Fig. 189 shows the characteristic greenish color of the water tank with a transparency of up to 10 cm. [110]

Fig. 189 Coloring of the water reservoir CP - Nad Jazerom Košice

A revitalizing device consisting of the largest star electrode with a diameter of 1 000 mm, a circular float, a diode rectifier and an electrical distribution box was used to carry out the experiment to reduce the occurrence of cyanobacteria Fig. 190.

Fig. 190 Float device with star electrode on the recreation area of the CP - Nad Jazerom Košice

Fixing the star electrode to the float device was using a rope in the center of the rib of the float device, which was submerged at a depth of 0,8 m (Fig. 191 b). Since the average depth of the Lake is 2,6 m and the terrain of the bottom is uneven, the optimal depth of the electrode suspension in such lakes is up to 1 m. [110]

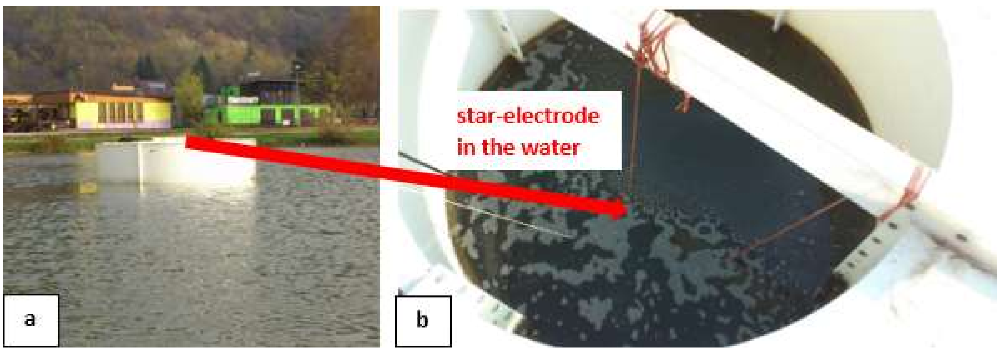


Fig. 191 Fixing the star electrode on the rib of the float device [110]

Available economic possibilities and the Local Authority Košice - Nad Jazerom allowed to conduct the experiment continuously 24 hours a day throughout the summer tourist season. After starting the source at a voltage of 40 V, bubbles were visually observed on the surface of the water surface, and around the star electrode, the spectrum of the electric field was clearly formed (Fig. 191 b). The silos forming the spectrum of the electric field spread on the surface of the tank, and after 30 minutes a thin layer of flotation was formed in the center of the circular float. During the course of the electro flotation method on the Lake, no mortality of other living organisms in the water reservoir was observed.

Already after a week of the experiment, changes in coloration and improvement of water transparency were visible on the water surface of Lake - CP Nad Jazerom. The necessity of a given revitalization method is its long-term action on the given water surface, the result being the elimination of sies and the improvement of other water properties.

At regular intervals, a flotate was removed from the inside of the revitalization plant using synthetic fabric to reduce the amount of cyanobacteria in the study area.

The following Fig. 192 shows the star electrode before and after electro flotation applications on the recreation area of CP - Nad Jazerom in Košice.

Fig. 192 Largest star electrode before and after electro flotation applications on the recreation area of the CP - Nad Jazerom in Košice [110]

6.13.3.3. Evaluation of the experiment

The main objective of the project and scientific and research activities at DEE, FME, TU of Košice was to solve problems of disposal of sieveds in stagnant waters and therefore it is important to have the possibility to recognize microorganisms in these waters i.e. algae, siemia, other aquatic animals in relation to each other (e.g. impact of electrolysis on aquatic population, frogs, crayfish, etc., but also a negative consequence of the appearance of sies on this population, but above all on humans). For these activities, it is necessary to monitor individual indicators of water quality in the long term, as well as monitoring of macro and micro flora or fauna on the experimental water surface. [110]

Characteristics of new possibilities of activities in the laboratory in the department [110]:

- determination of the amount of KTJs of bacteria, sie dossies, pathogenic elements,
- determination of the characteristics of water chemistry,

- measurement of quantitative characteristics of the presence of undesirable substances in water,
- measurement of adhesion of organic flotations on pantographs,
- determination of the methods of handling organic flotation.

All these activities are enabled by the new instrumentation of the laboratory with Hach lange DR 2800 spectral analyzer (Fig. 194) and the olympus BX51 light microscope (Fig. 193) with a computer that will make it easier for us to better analyses and subsequently process the results. Digital views of microscopic life in water in laboratory conditions are on Fig. 196 to Fig. 202.

Fig. 193 Light microscope with computer

Fig. 194 Spectrophotometer

Currently, the laboratory is supplemented by water sampling equipment, water quality measurement, METTLER TOLEDO MS205DU analytical scales (Fig. 195) for quantitative sample measurements and special equipment is being produced. The light microscope allowed us to digitally image microscopic life in a sample of water from the aforementioned City Part - Nad Jazerom in Košice. [110]

Fig. 195 Analytical balances

From the flotation created in the center of the float device, sample A (Fig. 203) was taken and microscopic analysis was subjected to microscopic analysis at the Regional Public Health Office based in Košice together with sample B (Fig. 203) before electro flotation. [110]

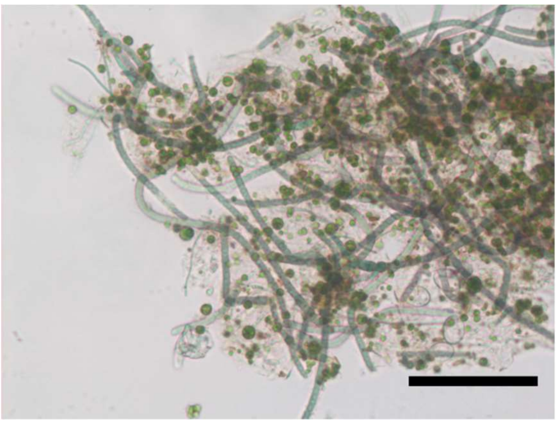


Fig. 196 Filaments cyanobacteria and green algae (BF) [140]

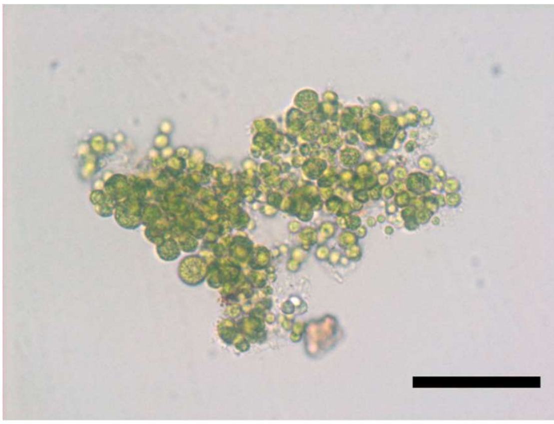


Fig. 197 Green algae (BF) [140]

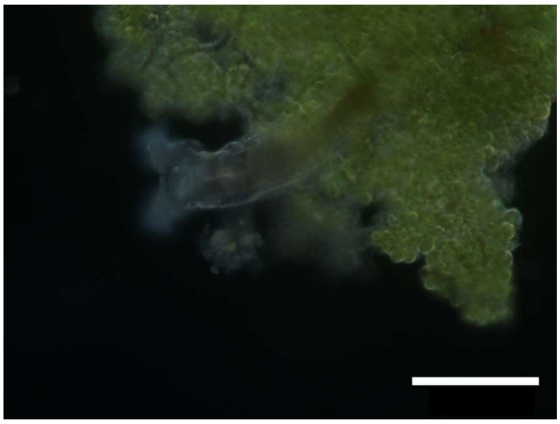


Fig. 198 Rotifera, green algae (DF) [140]

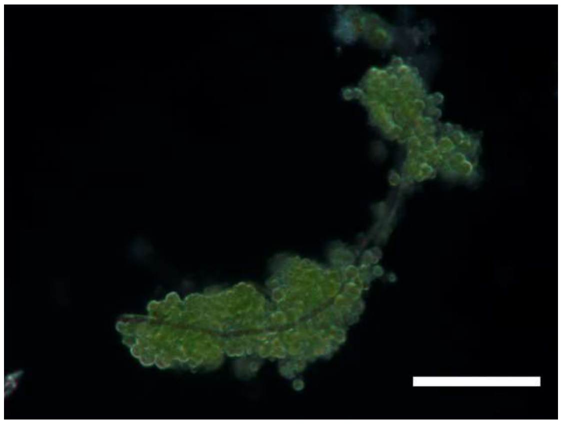


Fig. 199 Green algae, cyanobacteria (DF) [140]

Fig. 200 Weeled algae [140]

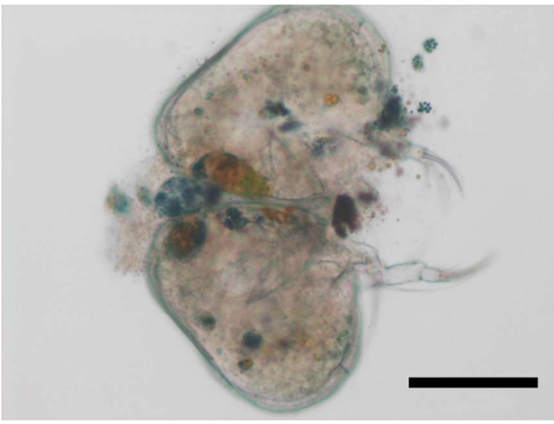


Fig. 201 Plankton (Cladocera) [140]

Fig. 202 Plankton (Protozoa) [140]

Fig. 203 Samples [110]

In the samples examined under laboratory conditions of the Department of Process and Environmental Engineering, living microorganisms - Daphnia and living green algae, as well as clumps of cyanobacteria, algae cells and chloroplasts were observed. No significant changes or disruptions to the cell wall on the sieles before and after electro flotation were observed in the observation. [139]

The examined samples were subjected to microscopic analysis at the Regional Public Health Authority to analyses the condition of the cyanobacteria cells for which the Bresser Bioscience Trino 1000 microscope was used, which had the necessary magnification to observe the condition of the cyanobacteria cells. The above micro-organisms and single-celled fibrous and spherical-shaped retinas were observed in the samples. From the flotation (sample A), a broken sieve fibre (Fig. 204 a)) and a damaged spherical sieve cell wall (Fig. 204 a)), were observed (Fig. 204 b)).

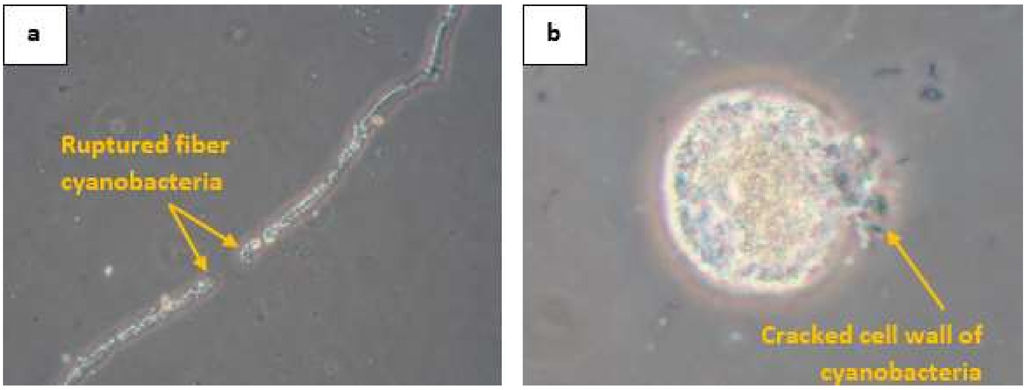


Fig. 204 Damage to the structure of the sieves after electro flotation [139]

By upsetting the cell wall not caused by mechanical interventions, it can damage both antibodies and some enzymes. By exposing the cyanobacteria cell to a large intracellular osmotic pressure, the plasma membrane was agitated, i.e. the cell wall burst. By rupturing the membrane, the damaged cell decomposes with the help of enzymes. [139]

6.13.3.4. Conclusion of the Experiment

The occurrence of water flowers, in water reservoirs, recreational waters and ponds can be well observed especially in the summer months in stable weather. The consequence of the overpopulation of cyanobacteria is the formation of a water flower, restricts water, fish and recreational use of water reservoirs, therefore the Department of Process and Environmental Engineering of FME, TU of Košice decided to combat these influences and proposed a facility for the disposal of cyanobacteria using the electro electro flotation method. [139]

With this method, the sieved of sieved, as well as green algae, to the surface of the water. The rest of the macro and micro life survived without any changes. By breaking and rupturing the plasma membrane of the cyanobacteria cell, the development of reins was prevented. Enzymes caused the cell to break down, making the cyanobacteria dead. The remains of the cells of the cyanobacteria have been sedimented at the bottom of the water surface and serve as food for aquatic organisms. [139]

The measured resulting values and microbiological observations confirmed the effectiveness of the proposed revitalization facility for the disposal of sieved plants. On the water surface of the Lake in Košice, the continuous electro flotation method during the summer tourist season improved the transparency of the water and there was a decrease in the occurrence of cyanobacteria and cyanobacteria water flower on the surface of the area under investigation. [139]

By designing the technical equipment and its experimental verification of the disposal of sieved on the water reservoir using the electrolytic method, a flotation was created, which would have to be collected from the surface of the level using a collection device, and therefore there is room for the emergence of such a technical device for collecting this flotation. [139]

6.13.4 Catamaran Equipment for the Collection of Neutralized Cyanobacteria and Algae

As already mentioned, the proposed catamaran device is used secondarily after the action of the electrolytic device. [123]

The following CAD systems were used to solve the basic design variants of the catamaran and their creation, load capacity (Fig. 205): AutoCAD, SketchUP, Pro/Engineer. [123]

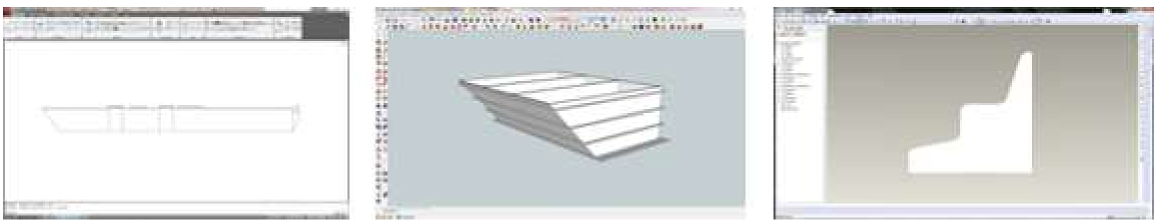
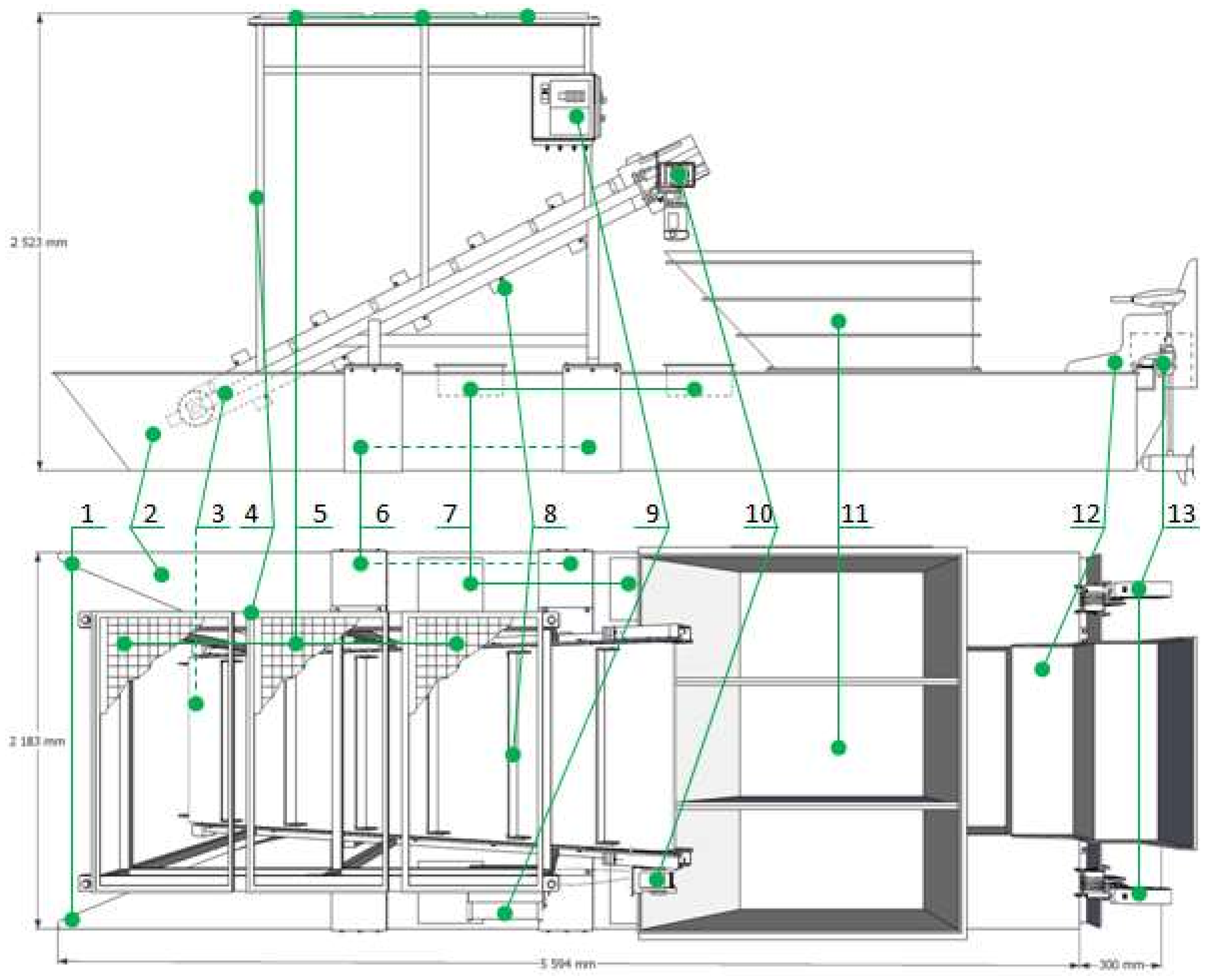


Fig. 205 CAD systems [123]

6.13.4.1. Canonization Solutions of Catamaran Equipment

The aim was to design a design solution for a catamaran device, which will be used to collect a water flower from the surface of the lake, reservoirs and ponds [123]. In the following Fig. 206 is a construction diagram of a catamaran device. The equipment for collecting impurities in stagnant waters is currently protected as a patent and utility model as well as a PCT application. [123]



Legend: 1 - jaws, 2 - floats, 3 - belt press, 4 - belt press frame and solar panels, 5 - solar panels, 6 - removable connection of floats with belt frame, 7 - battery cartridge, 8 - ejector, 9 - electric motor control unit,10 - belt press electric motor, 11 - collection container, 12 - seat, 13 - catamaran drive electric motors

Fig. 206 Construction scheme of catamaran device [123]

Fig. 207 3D view of catamaran equipment

Floats

Due to the fact that we do not need a lot of speed to change cyanobacteria and algae from the surface, nor to change direction sharply, the shape of floats narrowed from the inside was designed (Fig. 208). The cyanobacteria and algae collector will thus collect dirt better and more efficiently, and it is also more acceptable from a constructional point of view. The design also considered the location of the batteries, which will be incorporated in the floats of floats. The floats are made of polypropylene material. Dimensions of floats: width: 500 mm, height: 500 mm, length: 5 894 mm. [110]

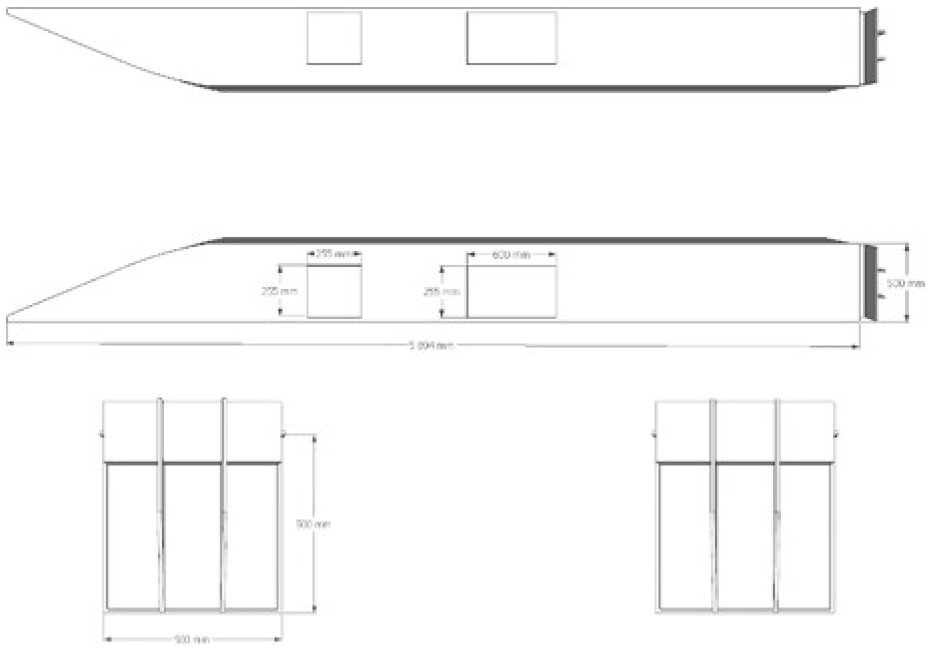


Fig. 208 Float scheme [123]

A real view of the floats narrowed from the inside is shown on (Fig. 209).

Fig. 209 Real view of floats narrowed from the inside [123]

Collection container

The collection container (Fig. 210) is designed to be as large as possible to collect the greater amount of semi-liquid water flower from the surface. In this case, polypropylene was also chosen as the material. Dimensions of the collection container: width: 1 499 mm, height: 1 000 mm, length: 1 950 mm. [110]

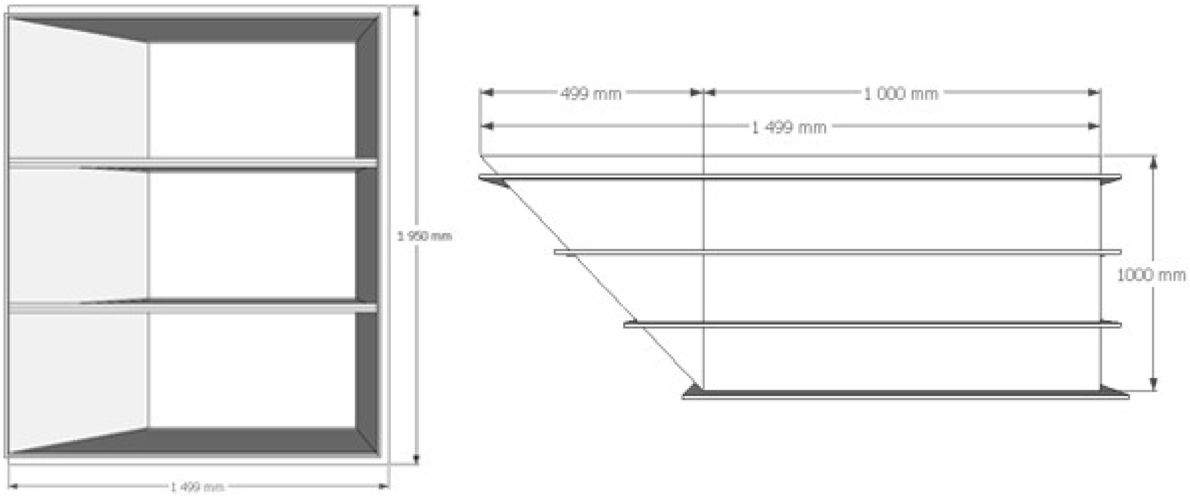


Fig. 210 Collection container scheme

A real view of the collection container is shown in the following (Fig. 211).

Fig. 211 A real view of the collection container [123]

Seat

The seat (Fig. 212) was designed for a crew of two (one member for the control of catamaran drive electric motors and the other member for the control and operation of the belt press). This part is also made of polypropylene material. Seat dimensions: width: 842 mm, height: 1000 mm, length: 1 383 mm. [110]

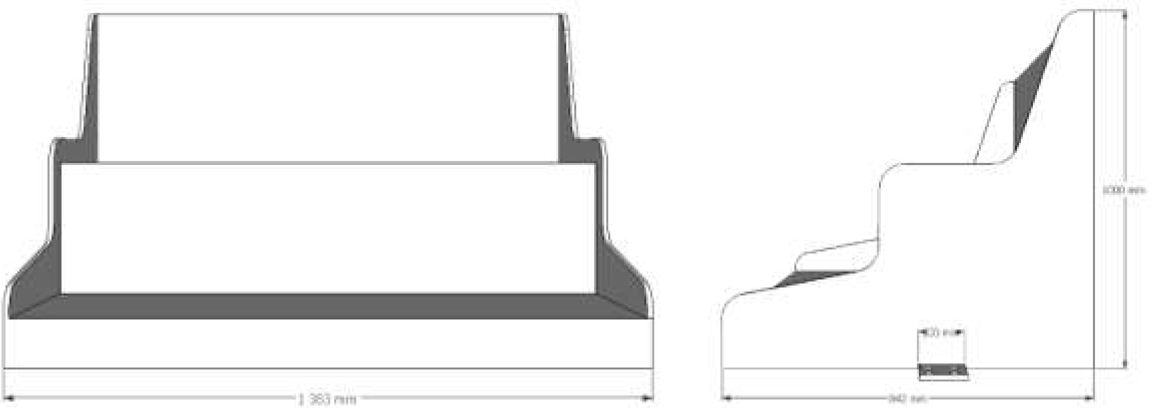


Fig. 212 Seat scheme

A real view of the seat is shown in the following (Fig. 213).

Fig. 213 Reálny pohľad na sedadlo [123]

Polypropylene compote

Polypropylene compote (PPC) is a material with excellent chemical resistance and good electro-insulating properties with almost zero water absorption. Polypropylene is a plastic that is characterized by healthlessness is also well weldable, moldable, machineable. It is UV resistant and color-stable, not prone to internal stress. This plastic is intended for external use. Possibility of use -40 °C to 130 °C. The following Fig. 214 shows the detail of the PPC material. [110]

Fig. 214 PPC material detail

Design of strip press and solar panels

The design, which holds the floats in a mutual position, has the function of a frame (Fig. 216), which ensures floats against mutual displacement. The frame is attached to floats using a removable screw joint (Fig. 218), which also serves as the supporting structure of a belt press, a separate electric motor, as well as a control unit of the belt press electric motor, a transformation box and solar panels located on the top of the structure. [110]

The frame of the structure is made of material that is resistant to corrosion and oxidation, due to the conditions in which the catamaran device will work, the material STN 426937 A of stainless steel of dimension: 80 mm x 40 mm x 2 mm of the icle profile (Fig. 219) was designed. The following Fig. 215 shows the design scheme of the belt press and solar panels. [110]

Frame dimensions: width: 1 383 mm, height: 2 000 mm, length: 3 500 mm. The following Fig. 215 shows a real view of the construction of the belt press and solar panels. [110]

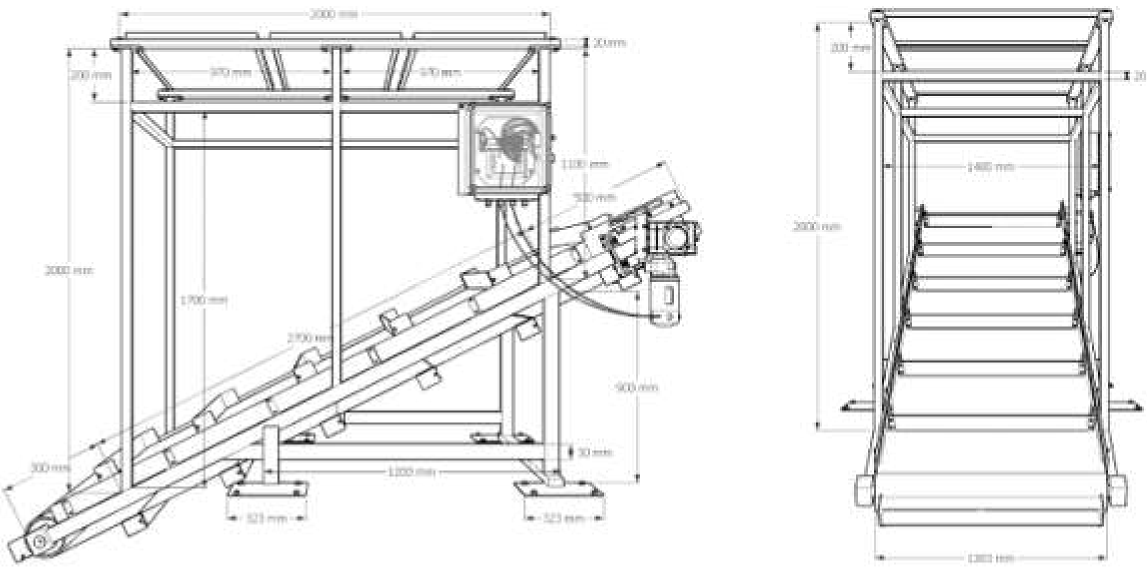


Fig. 215 Strip press and solar panel construction scheme [123]

Fig. 216 Real view of the destruction of the belt press and solar panels [123]

Dimensions of the detachable screw joint: width: 420 mm, height: 460, length: 323 mm. In the following Fig. 216 is a diagram of a detachable screw connection.

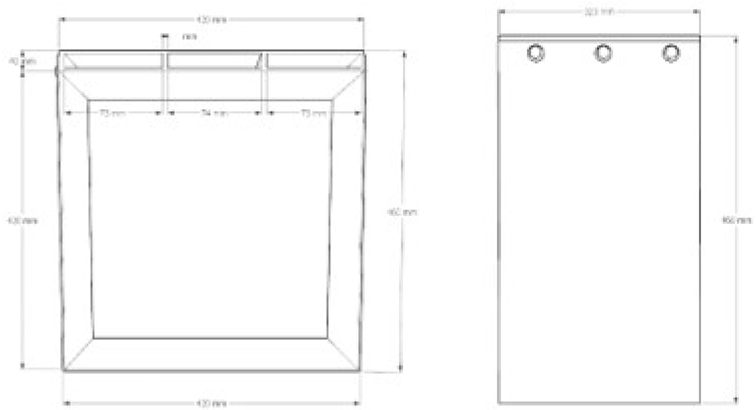


Fig. 217 Diagram of the removable screw joint [123]

The following Fig. 218 shows a real view of the removable screw joint.

Fig. 218 Real view of the removable screw joint [123]

The following Fig. 219 shows a real view of the jaccle profile of the belt press frame.

Fig. 219 Jacline profile of belt press frame [123]

Catamaran equipment

Principle of equipment

As the catamaran moves forward, the leading jaws located in the front, tapered on the inside, guide the cyanobacteria from the water surface to the belt press. Sufficient float draft and ramp speed must be ensured to effectively remove cyanobacteria. The cyanobacteria captured on the conveyor of the belt press proceed further along the press, which carries them above the surface. Excess water free of cyanobacteria flows down the belt and returns to the lake. Below the belt press at the end there is a collection container into which the captured cyanobacteria fall. The device works on an electric drive, energy is supplied from batteries in the number of 10 pieces (5 on each side), which simultaneously drive the electric motor of the belt press as well as the electric motors of the catamaran drive device. The recharging of these batteries is ensured by means of photovoltaic panels, which are placed on the roof structure of the vessel. Catamaran equipment is controlled manually, remotely or using a global positioning system [110].

From a safety point of view, each crew member must wear a life jacket. Real views of the catamaran device are shown in Fig. 220.

Fig. 220 Principle of catamaran equipment [110]

Principle of wiring of the electric motor of the belt press

The electricity generated by photovoltaic cells passes through the solar rectifier (Solutronic 2500 W), the charging regulator (BlueSolar DUO 12/24V-20A) through the electric motor control housing (VX-R1), which is used to directly drive the belt press electric motor (TRANSTECNO ECMP070/056/030 U), as well as for recharging the batteries (A512/60 A). Batteries with a number of two pieces are connected in series. The next figure is Fig. 221 shows the scheme of the TRANSTECNO electric motor. [110]

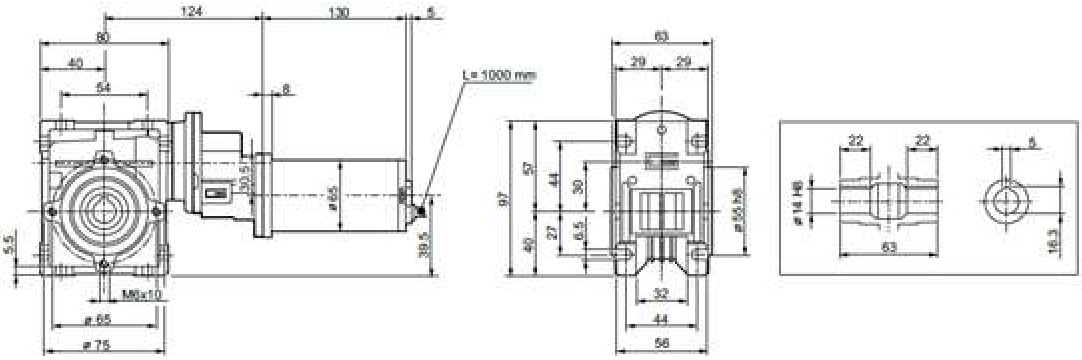


Fig. 221 TRANSTECNO ECMP070/056/030 U Electric Motor Scheme [123]

In Tab. 27, the technical parameters of the TRANSTECNO ECMP070/056/030 U electric motor are indicated.

Tab. 27

Technical parameters of the belt press electric motor [123]

Total transfer	28,5 - 857
Total output torque	15 - 1022 Nm
CMP - pre-stage transfer	i = 3
CMPU - pre-stage transfer	i = 5.7 or 8.57
Weight	7.1 kg
Bearing	Ballpoint
Maximum current consumption	35,5 A
Power	24 V
Number of magnets	4
Design	aluminium, cast iron
Diameter	110 mm
Dimensions	97 x 63 x 299 mm
Feat	600 W

Real views of the TRANSTECNO ECMP070/056/030 U electric motor are shown in Fig. 222 below.

Fig. 222 Real views of the TRANSTECNO ECMP070/056/030 U electric motor [123]

The following Fig. 223 shows the electric motor cabinet (VX-R1).

Fig. 223 Real views of the electric motor control box (VX-R1) [123]

As the catamaran works outdoors and the weather conditions are connected, the solar rectifiers as well as the charge controllers must be housed in a distribution box that is mounted on the left side of the solar panel frame (Fig. 224). [110]

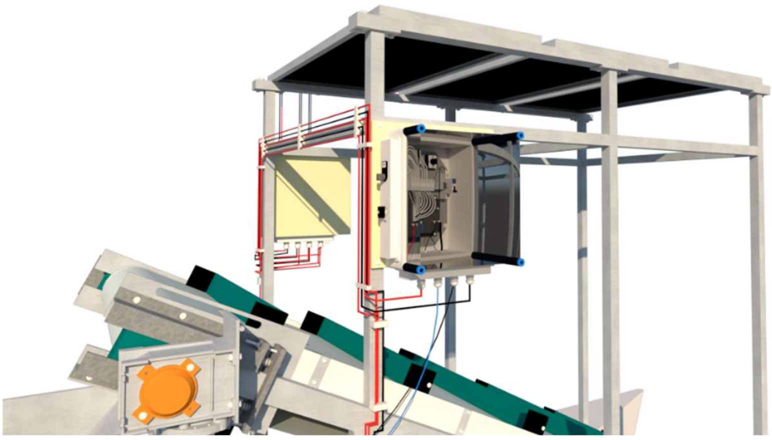


Fig. 224 3D view of the distribution box with electrical subpoposents [123]

In the next Tab. 28 the individual structural parts of the catamaran-new installation are listed, as well as the total weight of the equipment. [110]

Tab. 28
Individual components of the catamaran plant [123]

Serial Number	Construction part	Material	Count [piece]	Weight [kg]
1	Battery	Lead/ gel	10	208
2	Belt press electric motor	Cast iron	1	5
3	Drive electric motors	Stainless steel, PVC, aluminum	2	19,4
4	Cabling	PVC, foam polyethylene, copper	15	12
5	Peas press	Perforated rubber, PVC	1	50
6	Floats	Polypropylene	2	300
7	Strip press and solar panel frame	Stainless steel	1	166
8	Solar panel frame	Stainless steel	1	14
9	Electric motor control unit	PVC, tin, lead	1	17
10	Disassemovable screw joint	Steel	4	160
11	Seat	Polypropylene	1	23
12	Solar panels	Silicon, aluminium	3	58,5
13	Transformation box	PVC, tin, lead	1	25
14	Cylinder driving	PVC	1	12
15	Cylinder driven	PVC	1	10
16	Collection container (empty)	Polypropylene	1	37
Total weight of equipment				**1 116,9***

Note: * the total weight of the device is 1 116,9 kg, without human weight (80 kg - 100 kg) and also without empty collection container (1 m^3 - 1 000 kg).

The following Fig. 225 shows views of the catamaran device.

Fig. 225 Real views of the catamaran facility [123]

7 THE BASIC COMPONENT OF THE ENVIRONMENT - AIR (ATMOSPHERE)

Atmosphere (Fig. 226) forms the outer spherical gaseous envelope of the planet Earth, which is formed simultaneously with its development from the beginning of the solar system. The **Earth's atmosphere** creates a boundary layer of the biosphere relative to space. Its structure and its physical - chemical properties on the one hand determines the intensity and spectral characteristics of solar radiation (energy) reaching the surface of terrestrial and aquatic ecosystems, on the other hand, some absorption of solar radiation by some gases contained in the atmosphere is the driving force behind the movement of huge air masses, which results in a constant change of meteorological parameters that are called weather (assessed over a longer scale are called climate, respectively climate). [11]

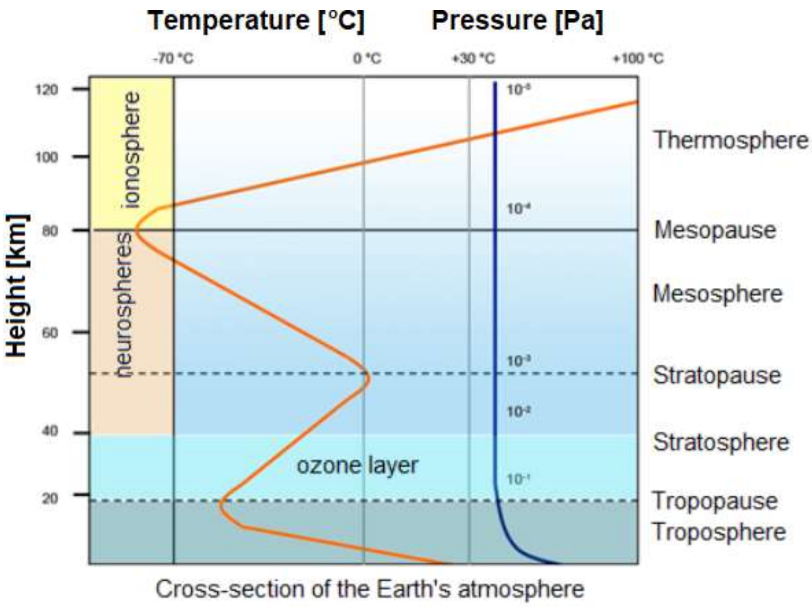


Fig. 226 The course of the temperature and pressure in the atmosphere depending on the amount [141]

7.1 Atmosphere and its Characteristics

During the geological evolution of the Earth we have also changed the chemical composition of the atmosphere, e.g. concentration of oxygen before 600 million. years was only 1/100 current transaction and only from the Carboniferous era, accompanied by massive vegetation has reached our level. The present condition is the result of a balance between the supply of various substances into the atmosphere, and their removal. [11]

Dry and clean air is a mixture of two main components - **nitrogen** (78,08 %) and **oxygen** (20,95 %). Next, air is containing 0,93 % **argon**, and about 0,03 % **carbon dioxide**. The remaining 0,01 % are trace gas components (especially noble gases - He, Ne, Kr, Xe). The real composition of the air, the proportions of the components varies with the content of water vapor. Highly variable can be amounts of air pollutants. In studying air pollution is an important indicator of the mean **residence time of the gas molecules in the atmosphere**. The average composition of ground atmospheric and its components remain in the atmosphere is shown in Tab. 29. [2]

Tab. 29
Average ground atmospheric composition and persistence of its components [142]

Type	volume concentration *		The average residence time in the atmosphere after the formation
	%	ppm (‰)	
Still			
Nitrogen	78,084		10^6 years
Oxygen	20,946		$5,10^3$ years
Argon	0,934		-
Neon		18,8	-
Helium		5,24	10^7 years
Krypton		1,14	-
Xenon		0,087	
Variable			
CO_2		330	5 - 6 years
CH_4		1,3 - 1,6	4 - 7 years
H_2		0,5	6 - 8 years
N_2O		0,25 - 0,35	25 years
O_3		$(1 - 5).10^{-2}$	2 years
Highi variable			
Water			10 days
CO		0,5 - 0,25	0,2 - 0,5 years
NO_2			8 - 10 days
NH_3			5 days
SO_2			2 days

Legend: * Data relate so. "*Clean areas*" without significant local anthropogenic pollution

In nature, the O_2 and CO_2 feedback loop exists. As soon begins to rise O_2 content in the atmosphere, processes of photosynthesis are immediately slow down. Conversely, if the CO_2 begins to rise, the processes of photosynthesis in nature instantly accelerate. This mutual bond of the relationship between O_2 and CO_2 is extremely significant, because the natural way to sustain the current O_2 content in our atmosphere. [11]
The atmosphere is made up of several spherical layers of gas, the density of which direction decreases from the surface, which manifests itself in the decrease of the atmosphere of atmospheric pressure with height. While on the surface of the Earth is on average barometric pressure of 1013,25 hPa, 100 km of its value is only 0,1 Pa.

The total mass of the atmosphere is estimated to $5,137 \cdot 10^{18}$ kg, the total content of water vapor in the atmosphere is $1,24 \cdot 10^{16}$ kg, the average content of water vapor is 2,34 grams per kg of air. The complex of terrestrial and cosmic factors determine certain dynamic equilibrium, which manifests itself mainly in a characteristic vertical layering. In 1961, the International Commission for aerologie Convention on the vertical structure of the atmosphere according to the temperature versus the amount and split the next layer of the atmosphere (Fig. 226) [2]:

- troposphere,

- stratosphere,
- mesosphere,
- thermosphere.

Troposphere

It is the innermost layer of the atmosphere extending from sea level to a height of approximately 12 km. As a result of the Earth's rotation and dynamics of planetary circulation, this sphere flattened so that in the equator amounts to about 18 km, while at the poles only about 7 km. It is the densest area of the atmosphere, total about ¾ of its weight. The troposphere is the most vulnerable point of view of air pollution of the atmosphere, since it penetrate into all contaminants consistency (emissions) and the natural, and now increasingly from anthropogenic sources, and is in direct contact with the biosphere on Earth's surface. The temperature in this layer away from the Earth's surface drops to about - 80 °C. However, this trend does not apply at ground level from about 2 km above the surface, where there is intense heat exchange with the earth's surface. [11]

Stratosphere

Stratosphere reaches an average height of about 50 km with a predominant laminar flow. Temperature increases with height up to a value of about 0 °C due to absorption of ultraviolet solar radiation the molecules of oxygen (O_2) and ozone (O_3), which is in this layer formed from the oxygen just due to absorption. In the stratosphere, the air is in regular horizontal layers because the temperature inversion-bedding strongly suppresses vertical movements of air masses. The vertical exchange in the stratosphere is therefore very slow and pollutants that are reachable (various aerosols, ozone layer depleting gases, etc.) remain in it for a long time. [11]

Mesosphere

It reaches a height of about 80 km, the temperature in it again decreases from about 0 °C at Stratopause (thin layer separating the stratosphere from the mesosphere) down to - 90 °C to its upper limit. [11]

Thermosphere

It is the last realm of the atmosphere and harmoniously with cosmic ,,vacuum” without a clear boundary (approximately 800 to 1000 km). In the thermosphere the temperature rises again due to the increasing absorption spectra of the richest energetic solar radiation has nothing unprotected outer layer of the atmosphere. In its upper limit, the temperature reached around 1 000 °C. [11]

Earth is due to its shape and consequently its movements unevenly irradiated with sunlight. Earth's surface reflects or emits 42 % of incident radiation and the remaining 58 % is absorbed by the atmosphere and the earth's surface including hydrosphere. [11]

Earth's surface is heated unevenly due to the following reasons [2]:

- **different albedo** (the ratio between the reception and the reflected radiation, e.g. Snow versus asphalt),
- **various heat conduction into depth** (e.g. Land versus ocean),
- **varying the angle of incidence of sunlight**.

As a result of unequal heating of the Earth's surface, there is uneven heating of adjacent layers of the atmosphere. The volume of air that is warmer than the surrounding air, tend to rise due to lower specific weight of a buoyant force equal to the difference in density. Thus, a gravitational force between warmer and colder air mass. These upward current must be compensated by sinking currents. Climbing and descending movements have their dynamic effects influence on the formation of inhomogeneous (barostatic) pressure field on the Earth's surface. The rising of air masses below them create areas of reduced **barostatic pressure (depression**) and vice versa, declining air masses below them form areas of increased **barostatic pressure (anticyclone).** These pressure differences create a horizontal plane sufficient pressure differences. **Horizontal pressure gradients**, which are able to actuate the huge air mass for large. Earth is rotating due to the rotation system, where the moving mass acts Corriolis force that turns moving air masses in the northern hemisphere to the right, to the left in the southern hemisphere. The result of these forces is to create a rotating air flow. The resulting circular flow is describes in the horizontal plane as **the wind** (ground or height) and in the vertical plane as climbing and descending currents. [11]

Pressure i.e. **Barometric pressure** is proportional to air density and thus decreases with altitude. At sea level, at 0 °C the barometric pressure value 101,08 kPa. Air pressure is the total pressure of each of its components - oxygen, nitrogen and other gases. Each of the gases has its partial pressure. Air pressure is variable. Day and night varies in about 6 - hour intervals. Changes during the week, month and year. Changes in barometric pressure are a sensitive indicator of changes in the weather.

Another concept is the **dynamic pressure**. Expresses air pressure measured at the same altitude at different places the Earth's surface.

Heat feelings are the result of the interplay of three basic parameters - **air temperature, moisture** content and **movement**. If one of these variables changes, as well as the others. This file is called hydrothermal complex.

The **air temperature** varies during the year, but also during the day. Warmest lives between $13^{\underline{00}}$ hrs., afternoon hours. to $15^{\underline{00}}$ hrs., when the soil is warmest. With its cooling and cold air. The heated soil releases its heat air in several ways [2]:

- **leadership** (the layer with which it is in direct contact),
- **convection** (hot and upper layers of the atmosphere),
- **emissions** (hot air sunbeams),
- **evaporation** (water from the soil).

Thus, the warmest air is above the ground. The air temperature is measured by different types of thermometers. Areas with the same temperature for meteorological maps associated lines **- isotherms**.

Humidity - There are three concepts for assessing the amount of water vapor in the air, namely [11]:

- absolute humidity - refers to the actual amount of water vapor at a certain temperature and pressure,
- the maximum humidity - the amount of water which may take the air at a certain temperature and pressure,
- relative humidity - is given in percentages calculated on the basis of the absolute maximum value and humidity.

Man best tolerated relative humidity 40 - 65 %.

Air flow - air flows from points of higher pressure to places with lower barometric (barostatic) pressure. Air movement is referred to as wind. Winds are characterized by speed and direction. The **role of the atmosphere** in the system is the biosphere [11]:

- protection against ionizing radiation,
- thermoregulation earth's surface,
- ensuring biochemical cycles.

7.2 Atmospheric Pollution

One of the most endangered components of the natural environment is air, which is mainly due to the rapid growth of energy production, intensification of raw material extraction, industrial activities, transport and so on. [143]

In the field of air necessary to distinguish two notions [143]:

- air pollution,
- pollution of the air.

- **Air pollution** - discharge means (Bringing, emissions) of pollutants into the atmosphere. These substances directly or after chemical changes in the atmosphere affect the environment.
- **Pollution of the air** - indicate the presence (content IMIS) air pollutants.

The air is polluted [143]:

- discharge of the various materials into the atmosphere,
- give me extending directly in the air.

Air pollution indicates the state of the atmosphere, when in the air are in the number of present components for an indeterminate time adversely affecting the environment. Air pollution has its causes and consequences. The cause is emissions (releases) of air pollutants from various sources. The connection between cause and effect procured by the earth's atmosphere. Air pollutants are transported (conveyed) from the source to the recipient. Pollutants that occur in the surface layer of the atmosphere and detrimentally affecting human health, wildlife and material assets are classified as nuisance and those that reaches the earth's surface as a **deposition.** In the air are also ongoing changes in individual types of pollutants other and sometimes more dangerous than the original. Schematically, the dynamics of air pollution shown in Fig. 227.

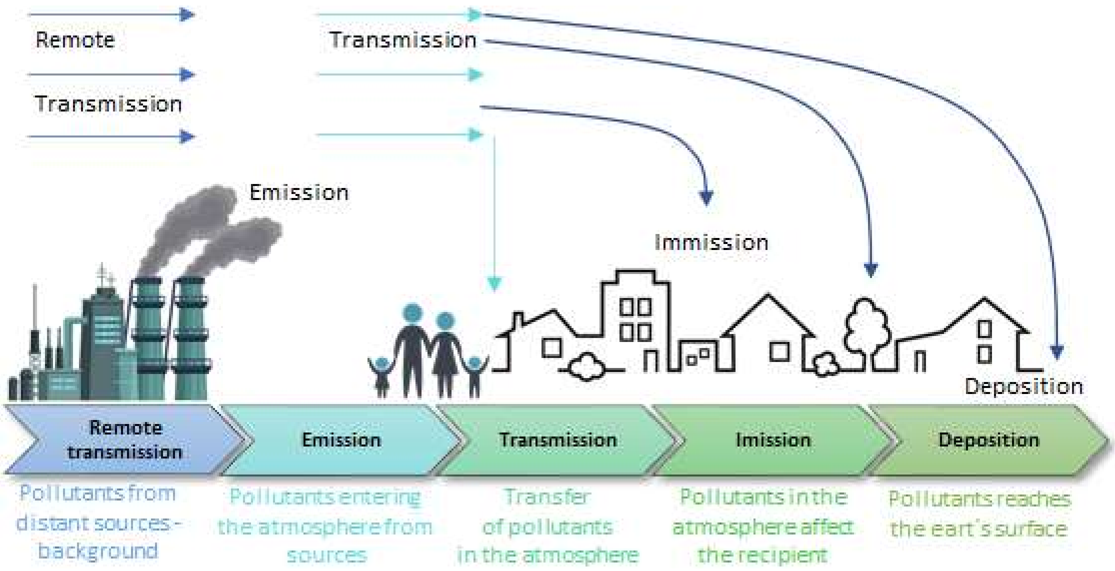


Fig. 227 Transmission of pollutants in the atmosphere

In order to compare and evaluate their pollution measurements of the air pollution, it is necessary to have a specific reference values for emissions and air pollutants. These reference values when they enter into a legal nature, then called the limit values.

Under current legislation can identify the three levels [143]:

- **emission limit** - the maximum amount of a pollutant released into the atmosphere from pollution sources,
- **air quality limit** - maximum permissible mass concentration of polluting substances contained in the atmosphere,
- **deposition limit** - the maximum amount of a pollutant established after impact per unit of land surface per unit time.

The concentration of gases and vapors is expressed as [143]:

- by the proportion composition in % [% $_{vol}$, % $_{mass}$],
- mass concentration related to the volume unit [$mg.m^{-3}$, $\mu g.m^{-3}$],

- participative composition in ppm or ppb (vol or mass),
  Units ppm and ppb (parts per million and trillion)
  1 ppm_{vol} = 1 $cm^3.m^{-3}$ = 0,0001 % vol.
  1 ppm_{mass} = 1 $mg.kg^{-1}$ = 0,0001 % mass.

Note:

ppm_{vol} = ppm v - corresponds to the volume ratio 1:10^6 (1 $cm^3.m^{-3}$)
ppb_{vol} = ppb v - corresponds to the volume ratio 1:10^9 (1 $mm^3.m^{-3}$)
ppt_{vol} = ppt v - corresponds to the volume ratio 1:10^{12} ($10^{-3}.m^{-3}$)
(The term trillion has a value of 10^9 and trillion 10^{12}).

The concentration of solid polluting substances (SPS) is expressed as:

- mass concentration related to the unit volume [$mg.m^{-3}$, $\mu g.m^{-3}$],
- by share composition in ppt m_{mass},
- by the number of particles related to the unit of volume [number of $particles.m^{-3}$, cm^{-3}].

7.2.1 Sources of atmospheric pollution

Sources of pollution can be divided into two groups [11]:

- natural origin,
- anthropogenic origin.

The air is permanently polluted by substances of natural origin, such as [2]:

- dust from soil decay, sea salts, gases, volcanic dust, microbial, plant and animal components, etc.,
- cosmic dust that falls on the earth's surface and sediments,
- volcanic eruptions,
- volcanic gases,
- forest and steppe fires,
- sand storms wavy surfaces of seas and oceans,
- different types of bioaerosols.

Man-made air pollution is as old as mankind itself. Sources of pollution of anthropogenic origin can be divided according to their [2]:

- **focuses** - energy, industrial, transport, municipal (waste burning, etc.),
- **mobility** - stationary, mobile,
- **sizes** - in the current SR legislation (Act No. 478/2002 Coll. Act on air protection) stationary sources are divided into: large, medium and small,

- **places of discharge of polluting substances:** point (engine, chimney, etc.), linear (transportation routes), area (dumps, quarries, etc.) and volume (industrial accidents, nuclear explosions, etc.).

7.2.2 Air Pollutants

Air pollutant is one that either directly or after the changes, which it is subject in the atmosphere, damaging or threatening living organisms and the adverse impact on the environment. [3]

Air pollutants are classified according to various aspects [3]:

- **Depending on the point of origin are divided into:**
  - the primary antibodies, - to receive the air from natural sources or from human activity,
  - the secondary agents - generated directly in the air at atmospheric reaction.
- **Depending on the chemical and physical properties shall be grouped in**:
  - a sulfur compound,
  - a nitrogen compound,
  - of carbon compounds,
  - the halogen compounds,
  - radioactive substances,
  - a solid.
- **Aspects of human health effects:**
  - of allergens,
  - carcinogens,
  - the smells.
- **According to state:**
  - for gas,
  - a liquid,
  - a solid.

The classification of the pollutants in the physical state is shown in Fig. 228 [3]. Generally, the particles of solid, liquid and gaseous substances in air are referred to as aerosols. [2]

According to the method of formation, they are divided into [3]:

- dispersive - dispersed particles of solid or liquid substances in the air,
- condensing - by condensation of supersaturated vapors respectively. creating a non-volatile matter in mutual reactions of gases and vapors.

Often they occur as mixed aerosols formed by sputtering and evaporation (e.g. diesel engine exhaust gases, fumes and dust generated during electric welding, ...). [11]

The smallest aerosol particles reach sizes from 0,01 to 1 µm. They are formed mainly by sulphates, nitrates, chlorides and carbon based materials. Particles greater than 1,0 µm containing, as constituting elements of the earth's crust - silicon, carbon, calcium and iron. Other metals are contained in trace amounts (cadmium, chromium, copper, lead, zinc, magnesium, manganese and nickel). [2]

Particle size and their weight has a great influence on the movement of aerosols in the atmosphere. The life expectancy of aerosols are up to several months, during this time they get to the large distance from the source and their presence influences the chemical reactions occurring in the atmosphere. Chemical and physical properties of the aerosol particles varies over the course of their transmission in atmosphere. [11]

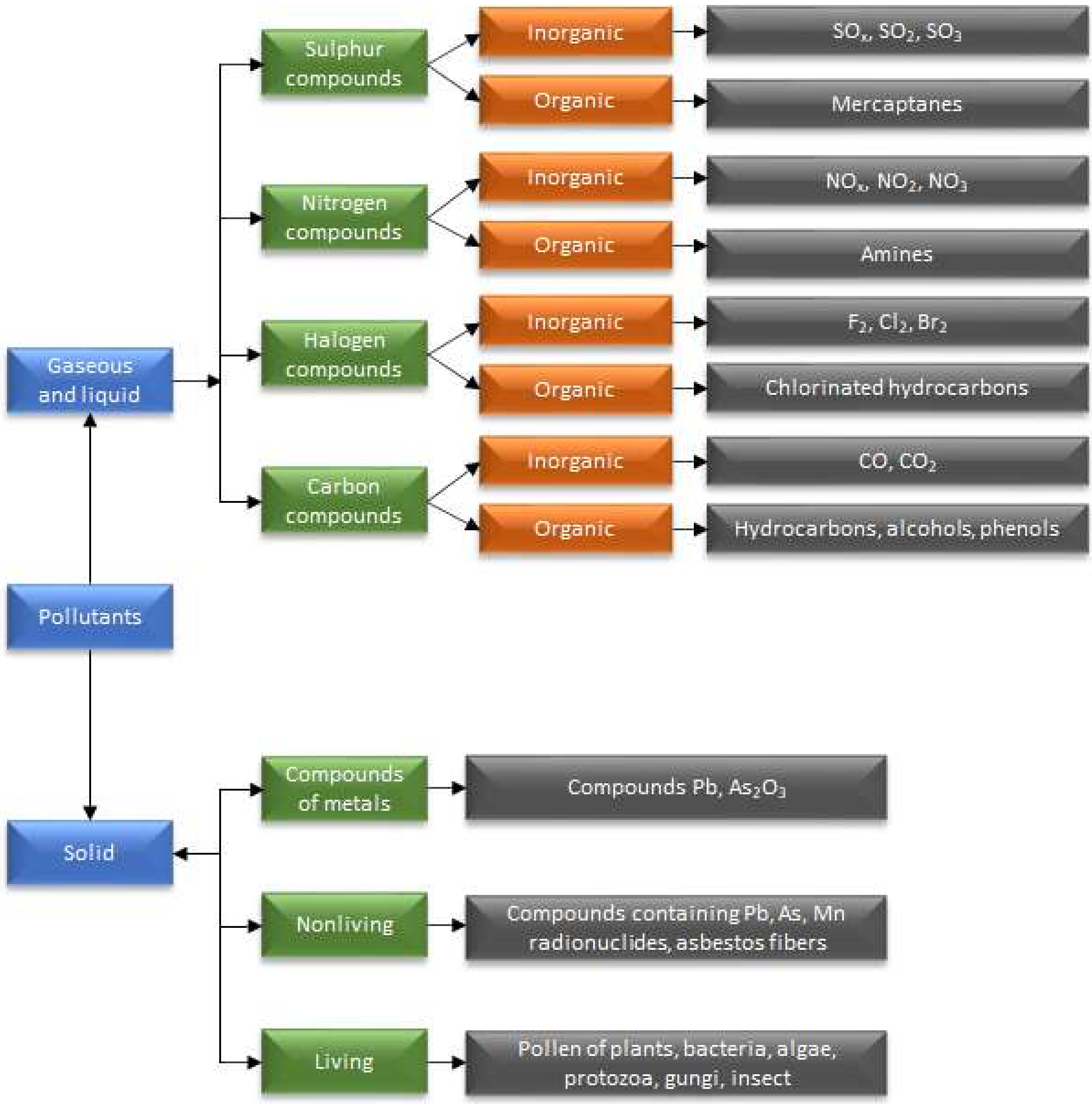


Fig. 228 Classification [3]

Pollutants emitted into the air are exposed to various influences, where there may be [3]:

- **photochemical changes,**

- **oxidative changes,**
- **catalytic changes,**
- **hydrolytic changes.**

At the simultaneous formation of other substances. An important role in these reactions plays **sunlight.**

Emission sources of solid and liquid particles in the air are varied. In urban areas at the air pollution significant role has a transportation and municipal resources. The result of air pollution in cities may be the product - in a negative sense - the chemical reactions in the atmosphere **smog**. The name smog is a combination of two English words: **smoke** and **fog**. Smog is characterized by air condition with a reduced distance at high air pollution by industrial emissions, vehicle emissions, etc. [2]

Distinction is made between two types of smog [3]:

- **London smog** (smog reduction) - a mixture of smoke from coal and has a high sulfur dioxide, which deliveres to smog strong reducing character (sometimes it is called also called as Acidic smog),
- **Los Angeles smog** (photochemical oxidant smog - a mixture of ozone (O_3) and peroxide organic compounds resulting from photochemical reactions between nitrogen oxides and friendly organic substances (gasoline vapors or fumes of incomplete combustion). Often it occurs on warm sunny days during rush hours.

7.2.2.1. Particulate Pollutants (PP)

The atmosphere there is a large amount of particulate pollutants - dust. Dust may arise from a variety of ways. [144]

By origin it can be divided into [144]:

- **natural,**
- **artificial.**

Natural dust - dust generated by erosion, volcanic dust and cosmic origin, fog, sea salt dust, smoke and dust generated during forest fires, dust of animal, plant and microorganism origin.

Dusts of animal and micro-organism origin - outdoor air of large cities has an average of 200 to 500 germs organisms in 1 m^3, in enclosed public spaces amount depends on the number of people and the intensity of the ventilation - from 600 to 2500 in 1 m^3.

Artificial dust - in every human activity. Each movement is connected with the friction, where the solids friction and change to the dust. [144]

Particulate substance - found in atmospheric pollution have a **different shape** and **size**. Particle shape and its size is one of the important physical properties of dust. An important feature is its dust particle size distribution. [144]

Other important characteristics of particulate substance are [2]:

- electrical and magnetic properties,
- ability to absorb and diffuse the light,
- wettability, solubility, adhesiveness,
- abrasiveness, explosion properties,
- weight, chemical composition, and the like.

Particulates according to the size of dust particles can be divided into [11]:

- **coarse dust** - particles larger than 50 µm,
- **fine dust** - particles 1 - 50 µm,
- **very fine dust** - particles smaller than 1 µm.

In view of harmfulness to the human body are important all dust particles of smaller size than 1 µm, as they can reach the airways of the lungs, from there to the blood stream and various particles of the body, namely [144]:

- **particles > 5 µm** - are retained, when exhaling in the airways. The greatest in the upper airways (nose, sinuses, pharynx), then the smaller the lower airway of the respiratory tract (larynx, trachea, bronchi),
- **particles from 0,25 to 5 µm** penetrate to terminal (end) parts of the respiratory tract that make up the alveoli,
- **particles of < 0,25 µm** due to its small size and weight are beginning to behave like gas molecules. Gradually decreasing their retention in the lungs and are largely exhaled.

Dust causes the greatest damage in the immediate vicinity of its origin, not only to the human organism, but also to plant life and animal life. [11] Very often, dust is the cause of the death of pollinating insects - bees. However, dust can also have a harmful effect on buildings and machinery. [144] Due to its depressing effect, a dusty environment reduces the desire to work, reduces the intensity of work. Its consequence can also be an increase in the number of accidents at the workplace. Dust also reduces the intensity of lighting and ultraviolet radiation, as a result of which the human body becomes less resistant to infections. Finally, flying dust can become a carrier of microorganisms harmful to human health. [2]

According to the effect on the human body, we can divide the particles /dust [144]:

- **dust with toxic effects** - powders consisting of particles of lead, arsenic, manganese penetrate the skin and digestive organs - their effect depends on the concentration in the air,

- **profibrogenic cash** - damage the track of the lungs, creating changes in their activity so. *"Pneumoconioses"*, for example. Silicosis - SiO_2, it is also dangerous asbestos-cement dust, coal dust,
- **inert dust** - a lengthy bronchitis - wood, cement and limestone powder,
- **dust with radioactive properties** - radioactive dust contains some radioactive substances. The source of the radioactive dust can be mining and processing of uranium, processing cells.

For workplaces with dusty operations are set out by hygiene rules maximum allowable concentrations of pollutants in the air, based on the conditions 8 - hour working day. To achieve acceptable emission limits for sources of pollution, by selecting of the optimal production technology and technical equipment to capture pollution, which are reduced already established emissions. [144]

7.2.2.2. Gaseous and Liquid Pollutants

Various gases and vapors are getting into the atmosphere by **natural way**. Gaseous pollutants are getting into the atmosphere, by various photochemical reactions, electrical discharges, volcanic activity and the like. Outside the immediate occurrence, however, the concentration of these gases and vapors very low. The largest number of these pollutants into the atmosphere gets a result of **human activity**. They are mainly combustion products, resulting from the ever increasing quantity of fuel used for heating, industry, in energy, transport, and other purposes. Another important source of these pollutants are mainly industrial technology, metallurgy and chemical industry and coke. [11]

Depending on the chemical and physical properties - air pollutants are classified into the following groups [2]:

- sulfur compounds,
- nitrogen compounds,
- carbon compounds,
- halogen compounds,
- radioactive substances and particles.

The behavior in the air for determine their **chemical and physical characteristics** and the total amount released into the atmosphere. This, of course, access to other factors, such as.: atmospheric conditions - **temperature, pressure, humidity, wind speed and direction and content of other polluting components in the air.**

Sulphur compounds

The sulfur compounds include **sulfur dioxide, trioxide, sulfuric acid, hydrogen sulfide, and various organic sulfur compounds.** The largest representation of: hydrogen sulfide (sulfide) -

46,1 %, sulfur dioxide - 33,2 %. From anthropogenic sources is the largest contributor of SO_2 and H_2S.

The presence of sulfur oxides in the atmosphere affects the increased corrosion of metallic materials, causing degradation and distortion of the structure of buildings, damage to works of art and monuments.

Sulphur dioxide SO_2

Sulphur dioxide is the most common ingredient of emissions. The highest amounts are getting into the atmosphere from the combustion of fossil fuels. The sulfur content in the coal is changing in depending on the origin and varies between 0,3 and 6,0 %, in fuel oil is about 2,5 % of sulfur. The carbon dioxide gets in the air it from volcanic activity in a lesser measure. The concentration of SO_2 in the clean atmosphere does not exceed 0,5 $\mu g.m^{-3}$. For dirty atmosphere, data moves from 500 to 2600 $\mu g.m^{-3}$. The median residence time of the SO_2 in the clean atmosphere is 2 to 6 days. In this time frame it can be moved to a distance of 1 000 km. Most of them, however, immediately after it gets into the atmosphere begins to react with the components present. [144]

The conversion of SO_2 to SO_3, absorption of SO_3 already formed (resp. H_2SO_4) in raindrop causes with HNO_3 increased acidity of rainfall.

The basic mechanism of removing SO_2 from the atmosphere takes place through its oxidation to SO_3. During the day, with low relative humidity prevalents oxidation of SO_2 in the presence of nitrogen oxides. At night and in wet weather, the SO_2 is absorbed in the water drops and the oxidation takes place in the liquid phase resulting sulfuric acid aerosol. Aerosol particles in the atmosphere gradually increasing. In the final stage they are washed out from the atmosphere the rainfall and snowfall. [2]

SO_3

Sulfur oxides formed during combustion of fossil fuels, the content is significantly lower than sulfur dioxide (SO_2). Small quantities produced in the manufacture of sulfuric acid, phosphate fertilizers. In the air, SO_3 reacts with water vapor to form sulfuric acid.

Hydrogen sulfide H_2S

The main source of hydrogen sulphide are natural processes - volcanic activity, biological processes of decomposition substances. Human activity is involved in the presence of only several percent by air - at the processing of crude oil, coal, pulp and in paper making. In the atmosphere, hydrogen is gradually changing due to the oxidative action of atmospheric oxygen with input from sunlight and through the hydrolysis reaction with atmospheric moisture to sulfuric acid.

The presence of sulfur oxides in the atmosphere affects the corrosion of metallic materials, causing degradation and distortion of the structure of buildings, damage to works of art and monuments. Similarly, the negative impact of sulfur oxides on humans - irritates eyes and lungs, worsen diseases of the respiratory system, increase mortality from other diseases. [2]

Nitrogen compounds

The most important compounds of nitrogen in respect to air pollution are **nitrous oxide, nitric oxide, nitrogen dioxide, and ammonia**. On its presence in the atmosphere it has a significant share of natural pollution. [2]

Nitrous oxide N_2O

Nitrous oxide is one of the stable atmospheric constituents, the only source of its occurrence are natural processes. The residence time in the atmosphere is estimated to 4 years. Its major part is returned to the surface, only 6 % diffuses - gradually dissolves, penetrates into the stratosphere, where expires. [144]

Nitric oxide NO

A substantial portion of nitric oxide derived from natural sources, is emitted to the atmosphere in large amounts by numerous biological processes, in particular by bacterial activity. A smaller share of its occurrence in the air, human activity - energy, local resources, transport. The residence time in the atmosphere is estimated to 4 days. The equilibrium conditions in the presence of oxygen, NO is oxidized to NO_2. In the mesosphere and thermosphere occurs fotodisociation of nitric oxde and its destruction. [2]

Nitrogen dioxide NO_2

Most nitrogen dioxide arises directly in the polluted atmosphere by oxidation of nitric oxide. Significantly, smaller amounts gets into the atmosphere from anthropogenic sources. NO_2 is presented in the gas flue of domestic heating, in the plume of industrial processes and in automobile exhaust.

For removing NO_2 from the atmosphere it occurs its oxidation and hydration to the formation of nitric acid. Nitric acid, like sulfuric acid is eluted in precipitation. In terms of air pollution is most important photolysis NO_2, which can initiate the formation of photochemical smog. Of all the oxides of nitrogen play a role in the most serious issues of air only NO and NO_2, which is generally by the abbreviated term NO_x. The presence of NO_x in the air has a negative effect on the human body - irritates the lungs, impairs heart disease and respiratory tract is involved in the formation of carcinogens. [11]

Ammonia NH_3

The highest amounts of ammonia formed during the biological decomposition of organic matter and in the reduction of NO_2 respectively NO_3. In particular, decomposition processes of plant and animal substances released into the atmosphere considerable amounts of ammonia, accompanied also developed various amines. During transformations in living organisms occurs NH_3 as a product of metabolism and is excreted in the urine as urea. Anthropogenic sources of ammonia in the air, the chemical industry, production of fertilizers and urea, industrial waste. [11]

Ammonia gas is reacted in an atmosphere with sulfuric acid, respectively. nitric arise sulfate, nitrate. Self-cleaning processes in the atmosphere - is sedimentation. Washout by raindrop, enable to remove the arisen salts from the air. The dwell time is estimated at about 7 days. Human feels irritation by ammonia at a concentration of 0,1 mg^{-1}, the concentrations up to 0,14 mg^{-1} is bearable, above 0,7 mg^{-1} can be already dangerous for human life. Ammonia in high concentrations strongly irritates eye mucous membranes and respiratory tract and may cause severe damage to these organs may even result in the death of 'victim. [11]

Carbon compounds

The most important carbon compounds contributes in the air pollution, are carbon monoxide, carbon dioxide and hydrocarbons. Most of the compounds of carbon get into the atmosphere from natural sources - biological processes, forest fires, ...

Anthropogenic sources of carbon compounds in the air are industry and transport, they are concentrated mainly in the atmosphere of densely populated areas. [2]

Carbon monoxide CO

A substantial portion of the carbon monoxide formed in the atmosphere from the oxidation of methane by decomposition of chlorophyll, other sources include volcanic activity, forest fires, burning of fossil fuels, exhaust fumes of cars and planes, waste incineration and various chemical processes, most notably in its occurrence in air shares the transport. The residence time in the atmosphere is in the range of 0,1 to 0,3 part of the year, depending on the rate of removal of carbon monoxide from the atmosphere. Carbon monoxide on the entry into the atmosphere underlies to oxidation with the present components.

Impact on human organism: it is a substance that prevents the organism in the use of oxygen, worsens the heart disease, causes headaches, fatigue, and increases in higher concentrations - 750 $mg.m^{-3}$ causes death by suffocation. [144]

Carbon dioxide CO_2

Carbon dioxide is the fourth in the order of stable constituents of the atmosphere - 0,03 vol. %, daily concentration fluctuates, a maximum reaches at night. It changes during the year. The median residence time is estimated at 2 - 4 years.

Anthropogenic sources include mainly combustion processes. With increasing consumption of fossil fuels is constantly increasing CO_2 concentration (in the last 100 years has increased by 10 %). [2]

Down about 30 % of solar energy reflected back into space - planetary albedo. The heated ground surface emits energy in the form of long-wave infrared radiation. Some atmospheric contaminants that absorb radiation, part of re-emit it back to the surface and thawing it. Carbon dioxide in the atmosphere absorbs radiation of this wavelength region, thus contributing to warming the atmosphere. The greenhouse effect (green house effect) without anthropogenic influence is 30 °C. Unbalancing the climate system by man causing increases in concentrations of greenhouse gases - only consume the non-renewable energy sources leading to the issuance of approximately 5 billion tons of carbon into the atmosphere annually. There are other reasons for the rise of CO_2 in the atmosphere caused by changing surface albedo - extensive clearing of forests, especially tropical, as consumption is reduced CO_2 on photosynthesis and with it the amount of carbon dioxide exhausted from the troposphere and the planetary albedo changes - changes in cloud of aerosol in the air.

The main cause, however, is the growth of greenhouse gases: CO_2, CH_4, N_2O, O_3, in addition to CFCs. [144]

Hydrocarbons

The largest share of emissions of hydrocarbons to the atmosphere is methane CH_4, derived from natural sources, the residence time of CH_4 in the atmosphere is estimated to be 0,9 to 1,5 years. Anthropogenic activities from the total amount emitted into the atmosphere receives less than 5 % - combustion of gasoline, solvent evaporation, evaporation of oil, and the like. When the hydrocarbon into the ambient air as the products of combustion processes, react with other components of polluted air or are subject to photooxidation and allows for the formation of smog photooxidation. The negative impact of hydrocarbons on the human body - damage the respiratory system, cause cancer, damage the blood pigment, blood components. [11]

Halogens and halogen compounds

For a whole range of substances belonging to this group, the greatest significance is given of the amount emitted into the atmosphere and toxicity has **chlorine, hydrogen chloride, hydrogen fluoride and silicon tetrafluoride.**

Fluorine and fluorine compounds

Natural source of fluorine in the air is volcanic activity. Fluorine compounds are emitted into the atmosphere in different state from some industrial production and the combustion of coal. From industrial sources are the largest contributor to the aluminum plant, production of phosphate fertilizers, silicate industry, steel production. In most cases, waste gases containing gaseous hydrofluoric acid and silicon tetrafluoride. The fluorine emissions may contribute to the oil industry. [2]

HF - Hydrogen fluoride is reacted in an atmosphere with water vapor, and forms aerosols, which further results in the formation of fluoride. Exception of the gas HF, they can get into the air and solid particles - sodium fluoride and aluminum fluoride.

As well as the above-mentioned sulfur oxides, nitrogen, carbon and fluorine and its compounds adversely affect the health of humans, animals and plants. [2]

Chlorine and chlorine compounds

Chlorine and its compounds get into the ambient air from natural sources - volcanic gases from anthropogenic sources - and chloric bleaching process, chlorinated water, burning of plastics based on chlorinated hydrocarbons. Far as possible the presence of chlorine and chlorine compounds in the atmosphere contribute volcanic gases.

The major compounds in respect to air pollution are Cl_2 and HCl. Chlorine gas is a stable compound in moist air and forms a mist of fine droplets of acid.

In terms of air pollution have special status halogen derivatives - chlorinated hydrocarbons, which are both getting into the atmosphere from anthropogenic sources - plant protection products, industrial solvents, cleaning agents and extinguishing agents and also from natural sources - forest fires. [144]

The widespread and high consumption of chlorinated hydrocarbons in plant protection caused the contamination of the whole environment. A considerable risk in view of the toxicity of all living organisms is the DDT (dichlorodiphenyltrichloroethane). It is considerable resistant, durable, residence time in the atmosphere is estimated to be tens of years. From the atmosphere, it actually removes only the rain, a large proportion gets into the oceans. As the sea water almost insoluble, but soluble in fats, it collects in the organic matter.

From the group of the fluorocarbons have been Freon 12 and Freon 11 used as a cooling medium, in a carrier fluid dispensers. To present time it is not known processes that could be removed from the atmosphere. Their residence time in the atmosphere is estimated at several tens of years. Due to the chemical stability of CFCs can gradually diffuse from the lower layers of the atmosphere into the stratosphere, which violated a protective layer - ozone layer against solar radiation, which has devastating effects on living organisms.

At present, however, due to international measures produce ozone-depleting CFCs greatly reduced. [11]

Radioactive substances

The atmosphere within the chemical, biological and other processes occur and radioactive substances that build, transfer and changing constantly. Radionuclides present in the atmosphere have their origin either in nature itself or produces one controlled or uncontrolled nuclear reactions.

Impact on the human body - cause cancers and genetic defects resistance of the body, damage to eyes and skin. [2]

7.3 Dispersion of Air Pollutants

Pollutants - aerosol particles in the atmosphere are subject not only **chemical**, but also **physical changes** (movement and spread in space, turbulent diffusion, changes in the concentration of dilution, etc.). Dissemination and distribution of air pollution in the area around the source (i.e. Dispersion of pollutants or so. "*Self-cleaning air*") is influenced by four factors [145]:

- **resource itself** - its yield, temperature and output speed, height above terrain, time mode,
- **emission characteristics** - size, shape, specific gravity, electromagnetic properties,

- **meteorological influences,**
- **the influence of morphology and surface terrain.**

Favorable for pollutant dispersion is most preferred labile state, while undesirable condition is reversed (from the Latin word inversio - rollover). Temperature stratification may however be varied in different heights. It can pass from one state to another. The most common conditions of weather, without inversion, high and low, and a low inversion inversion seen schematically in Fig. 229. [145]

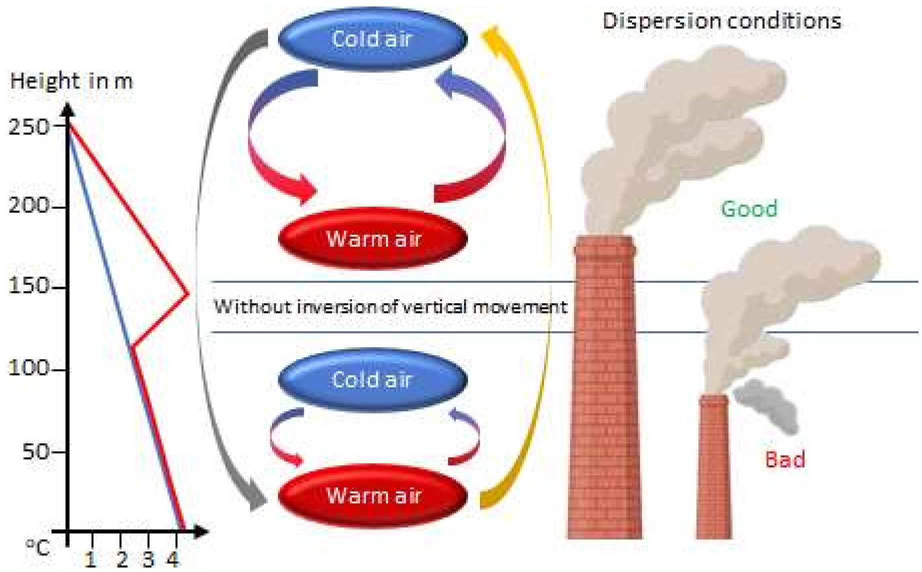


Fig. 229 Inversion and its consequences [11]

Often, they arise storey inversion (a clear calm nights) or inverse layers of up to 1000 m (in winter on a sunny day when no wind). They occur mainly in closed basins and valleys. Pollutants accumulate under inversion layer and do not scatter to the greater distance from the source. If the temperature inversion takes several days, the situation can become dangerous. Temperature inversions impossible temperature air circulation. [145]

Other meteorological factors that affect the dispersion and distribution of air pollution are [145]:

- **wind speed**,
- **wind,**
- **temperature-bedding,**
- **deduction**.

Emissions protruding from the chimney, which is the most common type of emission source, the influence of temperature drift in the direction of the first vertical and then horizontal wind. Plume from a source of air turbulence due to gradual expanding distance. Smoke is generally warmer than the surrounding air, so no wind rises straight up and the funnel is dispersed around the source. The smoke is warmer, the wind at the chimney weaker and more labile air, the higher it gets plume above the top of the chimney. Wind deflected plume and clogs various pollutants away from the source (depending on the weight of pollutants). The dispersion of smoke components in the air, in Fig. 230. [145]

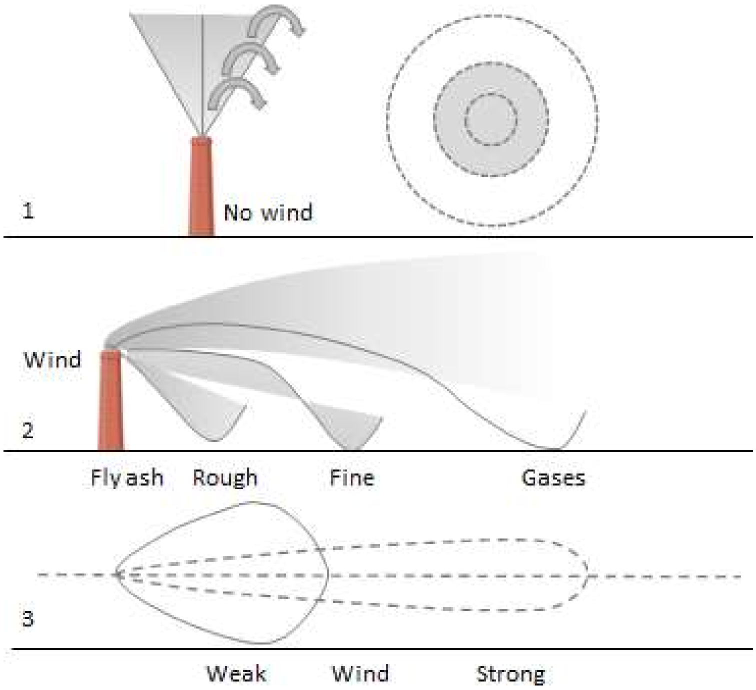


Fig. 230 Variance components of smoke in the air [11]

The shape of the plume depends on the physical conditions in the atmosphere (weather conditions). Fig. 231 gives the basic types of plume that may have [145]:

- **loop,**
- **conical shape,**
- **fan-shaped,**
- **fumigation.**

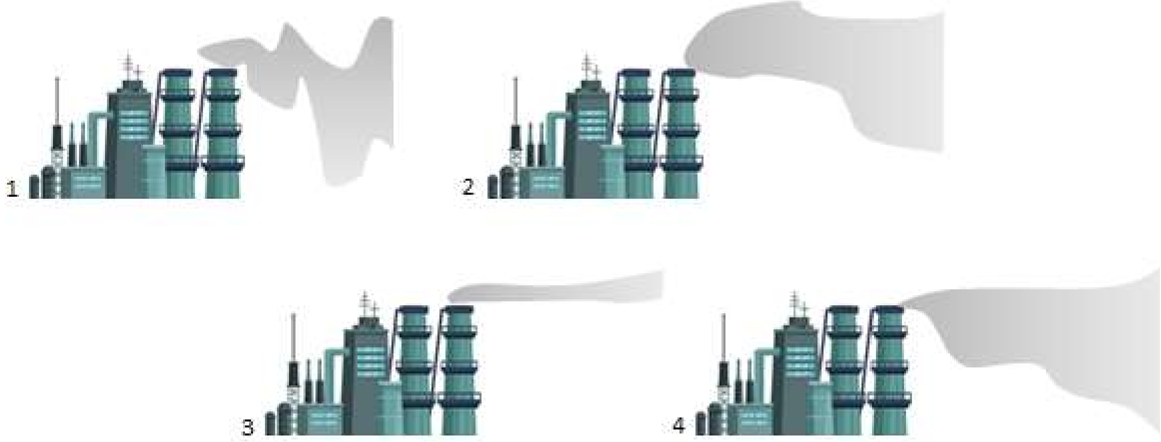


Fig. 231 Basic types of smoke plumes [2]

7.4 Removal and Disposal of Air Pollution

One of the most important conditions of human life is to ensure clean air not only in the workplace, but also in his everyday existence. Indoor and outdoor air pollutants pollute, which are the product of industrial activity. To ensure non-toxic pollution in general, it is necessary to capture and remove pollutants from the producer. [144]

To achieve the emission limits for sources of pollution is generally required in addition to the application of primary measures limiting emissions - an optimal choice of their own technology production, also use secondary measures - restricting already existing emissions.

7.4.1 Devices for Removing Particulate Matter

Particulates are removed from the waste gases so. condensate. Plants, in which the process is carried out as separators. The basis of any process separating solid and liquid particles of the separation of particles from a gas stream at the separation area. [145]

Features of force, which in this case involved the separation of the particles is determined by the principle of separation.

- **Gravity principle** - based on the action of gravity.
- **Inertial principle** - to use the inertia of particles flowing around obstacles.
- **Centrifugal principle** - applies to flow in a circular chamber and movement of the particles in the gas is given by the rotation effect of the centrifugal force.
- **Electric principle** - based on the action el. forces on charged particles.

And according to the name of the separator - gravitational, electric, and the like, in some cases, the same time applies more principles - filtration. [144]

The basic considerations for assessing the function of separation equipment include [145]:

- **separation efficiency** is defined as the ratio of the mass of particulates collected by the particulate trap on the weight of the incoming device,
- **pressure drop,** which determines a substantial part of energy to extract,
- **total operating and investment costs.**

According to **performance** separators are classified into two groups [2]:

- **Separators used primarily in industrial facilities.** Waste gas is cleaned to such an extend that it can be released into the open air - it meets the emission limits. This group includes e.g. cyclones, fabric filters, wet separators, electric separators, end etc.
- **separators for smaller amounts of pollutants**, the advanced treatment of air and gas is obtained. The air cleans to such a degree that it becomes physically- not harmful - different types of filters - in health care.

According to **physical principles** are separators divided into [11]:

- Dry mechanical separators (settling chambers, louvre separators, cyclones),
- wet separators (viral, level, current),

- filter separators,
- electrostatic separators,
- ultrasonic separators.

7.4.2 Removing a Restriction of Gaseous Pollutants

To reduce emissions of gaseous pollutants are used in a variety of physical and chemical principles and more recently biotechnology [145]:

- sorption - absorption, adsorption,
- response technology - oxidation, reduction, thermal and catalytic incineration,
- condensing technology,
- biotechnology.

Absorption

Absorption is the process, where the absorbed gas component is in contact with a suitable liquid. The absorption can be purely physical, in which the mass transfer from the gas to the liquid, is done by diffusion, and absorption with the use of chemical reactions - chemisorption, in which to capture the gas components is necessary less media than the physical absorption. [145]

Absorbing devices are divided into the following groups [145]:

- shower chamber, absorption towers,
- absorber with cloth or grate,
- absorbers with filling.

Shower chambers are devices, in which the purified gas stream in a suitable liquid is sprayed. It forms either water or suitable solution. They are simple devices that can be removed at the same time as dust. [2]

Absorbers with cloth or grate, allow thorough contact of gas with absorption liquid. They have the shape of vertical chambers round or quadrangular cross-section, in which the purified gas is passed upward from below through the screens, perforated screens or grids. The purified air is blown into the chamber from below, where it contacts the water spray from the nozzles. [2]

The absorbers used with the cartridge are used to increase the efficiency of one or more layers of filling of Raschig rings, coke or other material of large surface area. An absorbent solution flows down the cartridge and purified air flows through the layer counter currently or concurrently with the solution. The disadvantage of these absorbers is prone to clogging of the cartridge and complicated cleaning. [11]

Adsorption

Adsorption is a diffusion process, wherein the gaseous capture occurs on solid surfaces. It is a physical process, based on the action of van der Waals forces or surface by chemical adsorption, at which the chemical reaction between the adsorbed and the sorption agent to form a new compound. [11]

The solids, which are used for the adsorption of the porous granular material with a large internal surface. [11]

Physical sorption substance, as most commonly used one, is activated carbon with high surface area to 10^6 m^2kg^{-1}. The materials used for the adsorption of pollutants is also crushed coke, silica etc. [11]

Adsorption is useful for the removal of some of those contaminants, the removal of which other means would be uneconomic, dangerous or impossible e.g. many organic compounds can quite effectively removed by adsorption at higher concentrations or severe toxic or malodorous pollutants. [11]

Oxidation and reduction

In some cases the contaminants from industrial emissions can dispose of oxidation or reduction. Products of oxidation (reduction) may be the end products that may be less serious pollutants, or serve as an intermediate for the subsequent removal easier. [145]

Oxidation is the reaction of the pollutant with atmospheric oxygen. The simplest reaction is a thermal oxidation technology, that is burning, which is widely used in the petrochemical industry for the removal of hydrocarbons and other organic material to form CO_2, H_2O, etc.

Reduction is a process in which the pollutant is in contact with the reducing agent - carbon, CO and the like. The reduction is a process, where the pollutant is in contact with the reducing agent. To reduce the use of carbon C, carbon monoxide CO, hydrogen H_2 or other reducing agents - methane CH_4, ammonia NH_3. Thus, a major source of ammonia for example with oxides of nitrogen at 850 - 1050 °C to molecular N_2, or oxides of the sulfur converted to hydrogen sulfide, which is then further processed to sulfur process. [11]

Thermal oxidation - in many emissions from the chemical industry especially in petrochemical production and oil refining, are in the gas that gets into the air contained hydrocarbons and other organic substances that can be converted into CO_2 and H_2O, or other hygienic fumes. [145]

Condensing technology

Condensation of the vapor is passage and the gas phase into the liquid state. The condensation can be achieved either by cooling at a given pressure, or a change in pressure of cooling - press. Gaseous pollutant, when condensation is separated as a liquid. [2]

This separation takes place in a device referred to as capacitors. These are devices chamber through which a flow of polluted air is introduced from a source of pollutants and are cooled to a temperature such that harmful vapors are condensed and precipitated out of the air as a liquid. [11]

As the refrigerant used is often water, cooling mixtures or liquid nitrogen. Recognize the condensation of two ways [145]:

- **indirect** - refrigerant and cooling air is not directly on the exchange occurs through the walls of pipes,
- **direct** - refrigerant and air are mixed, water is injected into the polluted air nozzles in the chamber. To improve contact with droplets of coolant polluted air are inserted into the chambers and compartments bars.

Harmful vapors condensed, optionally together with the cooling liquid (in the case of injection capacitors), gathers at the bottom of the chambers of the capacitors receiving chambers. [11]

Biotechnology

Reducing substance concentrations provide microorganisms, whereas the most frequently used in the processing of sludge in sewage treatment plants - microorganisms in contact with the organic pollutants are converted to harmless elemental gases. [145]

7.5 Determination of the Concentration of Solid Aerosols in the Technological Operation of Surface Mining of Mineral Raw Materials (in a Quarry)

The environment and its protection together are one of the most important tasks of our society. As a result of scientific and technological development, the growth of the human population, and the globalization of the world, another important issue related to the damage and devastation of the environment comes to the forefront, namely, noise. Noise presents one of the most common environmental problems, which is also affected by the development of industry and transport. Noise presents unwanted, disturbing, or, in some cases, harmful sound that is transmitted through sound waves. Environmental noise is a natural part of human activity; its existence in the environment is related to different work, non-work activities, industries, or transport. At present, it is possible to talk about noise pollution. Noise pollution interferes in complex task performance, it may affect social behavior, and it may cause noise annoyance and noise-induced sleep disturbance [146, 147]. Generally, noise may be defined as unwanted sound and it is perceived as an environmental stressor. Basner et al. defined the non-auditory effects of noise as all of those effects on health and well-being that are caused by exposure to noise [148].

Environmental noise management is an important aspect of the environmental policy of the European Union [149]. Environmental noise is, as stipulated in the European Union (EU) policy, regulated by the Environmental Noise Directive (2002/49/EC). This directive, related to the process of the assessment and management of environmental noise, is also referred to as the “END”. This directive aims to define a common approach to prevent or reduce environmental noises. The basis of the environmental noise management is to develop EU measures to reduce the noise emitted by important sources, such as industrial activity. The most important elements are to monitor the environmental problems and create strategic noise maps (e.g., for roads, agglomeration, and industrial plants). This uses "L den" (day–evening–night equivalent level) and "L night" (night equivalent level) harmonized noise indicators. Another important role of this directive is to inform the public about noise exposure and its effects and to realize measures [150].

It is very important to emphasize that the usage condition of industrial units has a major and significant effect on the noise emissions [151]. Nowadays, a widely used concept for improving the life standard is to reduce the industrial noise, above all in industrial and residential mixed areas [152]. Industrial development, different, and also, in some cases, chaotic locations of manufacturing facilities which are near residential areas demands to realize noise level monitoring [152].

An interesting view of industrial noise solution was presented by Vasilyev [153], who used active noise and vibration control to reduce low-frequency noise and vibration in gas guide systems of power plants. This author explained that the impact of vibration and the related mechanical noise of industrial plants and joining mechanical systems may cause a significant impact on, for example, the reliability, productivity, durability, and other significant parameters [153]. The authors in [154, 155] conducted research on noise solution, dealing with the problems of vibration and noisiness, and they stated that the two are closely related.

An important part of measures to reduce noise is the proposal and verification process of the realized measures. It is also necessary to take into account the material selection, construction, and other parameters during this process [156, 157].

The problem of industrial noise and its impact on the environment was presented by Sadler, who analyzed the industrial noise generated by industrial installations, and then described a proposal about how to take into account the additional effect from other types of noise from the environment and other human activities in the described area [158]. During the evaluation of noise sources, it is important to evaluate the sound quality, and not just the sound quantity, because some sounds are very annoying for people [159]. Wzolek and Kukulski examined a methodological approach with the help of a case study with the main subject being the cumulation of industrial noise sources. These authors used the evaluation of cumulative noise levels for a new object realized by computational methods, as well as for the existing object, by measurement of or by help from a combination of measurement and computational methods [160].

Research of industrial noise was presented by Tomozei et al., who used mathematical modeling of noise pollution to preset a three-dimensional mathematical model. This model characterizes the variation of sound pressure level propagation and the variation of attenuation of the sound pressure level propagated in an enclosed space. The authors realized experimental measurements and mathematical modeling, taking into account the position of the acoustic screen for the noise source and the height of the used microphone for recording [161].

The use of mathematical modeling for the prediction of pollutants was also presented by Ani et al. (via MATLAB), who used the initial parameters for the calculation of pollutant distribution [162].

The possibility of industrial noise source localization and reduction in industrial plants was examined by Fiebig and Dabrowski, who identified main noise sources using an acoustic camera and the beamforming method. They also performed a sound level measurement on the main noise sources. Their research was presented in the form of an acoustic noise map with the help of LEQ Professional software, which also included the 3D geometry of the examined buildings inside the studied plant [163, 164].

An acoustic camera is a measurement tool that joined the field of acoustics a few years ago. This technology analyzes the actual sound scene, which consists of a superposition of different sound sources, and then combines them into a visual sound map. The basic principle relies on the accurate calculation of the specific runtime delays of acoustic sound emissions radiating from several sources to the individual microphones of an array. An acoustic map of the local sound pressure distribution at a given distance is calculated using the acoustic data of all simultaneously recorded microphone channels. The sound pressure level is displayed via color coding, similar to popular thermal imaging. The application of an acoustic camera was also presented in [165]. Bocher et al. conducted noise modeling in their research, and they described an open source form for the implementation of a noise mapping tool that is fully implemented in a geographic information system compliant with the Open Geospatial Consortium standards. The contribution of these authors made easier the formatting and harvesting of noise model input data and output data, linkage with population data, and also cartographic rendering [165]. The use of noise mapping is very important and necessary to ensure environmental noise control, as well as industrial noise control. Noise maps are established to obtain information for noise reduction planning [151], and noise mapping presents the best suitable way to present information on acoustic pollution [166].

One of the tasks of noise mapping is to investigate noise exposure in living areas and knowledge of noise situation in the surroundings of noise sources, particularly in connection with the development of residential and industrial areas, as well as transport axes in many urban areas. These types of maps are also useful for the determination of the minimal sound insulation of individual buildings necessary for acoustic comfort conditions [167].

In the literature review, it is possible to find publications related to the study of noise and noise mapping. For example publications [168 – 170] which are oriented to the area of transport (railway noise, airport noise, road noise). Another interesting publication is presented by the authors Lertsawat et al. They focused on the prediction of noise emissions from power plants using a mathematical model. They used the principles of outdoor sound propagation and developed a noise prediction model, providing an illustration of the accuracy level of the mathematical model [171].

The noise mapping of industrial sources was researched by Santos et al. [172]. They described the forms of applications of noise mapping for industrial sources, and additionally pointed to its potential in the design phase of existing installations for noise reduction plans.

They also created a general methodology for the noise mapping of industrial plants, consisting of input data collection, data processing and adjusting, modeling by software to compute noise emissions and propagation, and, at the end, the noise map production [172].

7.5.1 Materials and Methods

7.5.1.1. Determination of Sound Pressure Levels

The measurements were carried out in accordance with applicable national legislation and international standards (ISO 1996-1 Acoustics standards. Description, measurement and assessment of environmental noise. Part 1: Basic quantities and assessment procedures; ISO 1996-2 Acoustics. Description, measurement and assessment of environmental noise. Part 2: Determination of sound pressure levels) [173, 174].

For measurement of the sound pressure level, the Norsonic type 140 (Nor-140) sound analyzer with the Norsonic type 1225 (Nor-1225) microphone was used. The Nor-140 is a class 1 approved integrating sound level meter, while Nor-1 is a 1⁄2 free-field, 50 mV/Pa sensitivity microphone - a general purpose microphone covering the frequency range from 3,15 to 20 kHz, corresponding to class 1 of the sound level meter standard IEC (International Electronical Comminsion) 61672.

7.5.1.2. Sound Visualization

For sound visualization, the **gfai tech company** acoustic camera with a star microphone array, a 48-channel measurement system designed for outdoor applications, was used. A digital camera is taking an image of the noise emitting object. At the same time an exactly computed array of microphones acquires and records the sound waves emitted by the object. A specially developed software calculates a sound map and combines the acoustical and the optical images of the sound source. The acoustic camera can extend the time and frequency selectivity and add a location-selective component. With this method the sound signal is shown and also a sequence of acoustic images can be acquired-acoustic videos are generated. The measurement distances ranged from 4 to 200 m, while the frequency mapping ranged from 150 to 13 kHz. For acoustic cameras, the delay-and-sum beamforming method is the most widely known sound localization technique [175, 176].

7.5.1.3. Noise Mapping

The mathematical model-based noise map was created using the CADNA A version 3.6.117 software package with the relevant methodologies implemented. CADNA A meets the requirements for quality assurance of software for the calculation of sound outdoors according to the DIN 45687 and ISO 17534 series. For calculation purposes, the ISO 9613-2 standard was used. For calculating the noise maps, the software requires the sound power level data of each relevant noise point source. This was achieved by measuring the sound pressure level around the identified noise sources in the wastewater plant. An Acoustic Determinator is a tool that determines the sound power level of respective noise sources by measuring the sound pressure levels using reverse engineering methods, in accordance with ISO 8297 and other similar guidelines.

The first step of the noise map creation was to model the terrain, for which we set an appropriate ground factor for each part and also took into account vegetation. All noise sources were modeled as point sources, with only the air distribution pipe being a line source. Noise maps were then created with noise isophones at a height of 1,5 or 3 m above ground level, which were subsequently color coded in 5 dB steps. The height of the isophone and calculation points was chosen as 3 m because of the hilly terrain, in aid of better knowledge of the acoustic situation and the spread of noise at the location in question, and also because a large number of the houses have windows at this height.

7.5.2 Description of the Problem

The main task of the wastewater treatment process is to convert wastewaters into clean waters of the required quality. This fact means that this process has to respect the limits of the contaminants imposed by the legislation of the environment, for example, by the Water Quality No. 2000/60/EC directive [177]. In the case study the effect of wastewater treatment plant on the noise situation is described, as noise pollution is one of the major environmental problems. A biological wastewater treatment plant is a source of such noise. Herein, we chose a treatment plant that is used for treating wastewater from industry, as well as municipal wastewater, located between two villages approximately 200 m from the treatment plant site. Residents of these villages complain about the noise caused by this wastewater treatment plant. According to the operator of wastewater treatment plant, 13 noise complaints have been registered in the last three years (personally, phone, or mail).

7.5.2.1. Description of the Noise Source

The noise source that we evaluated was the operation of the wastewater treatment plant and, in particular, the individual pieces of equipment located on the treatment plant site. The operation of the treatment plant is continuous and the nature of the sound emitted by the equipment is stable. The treatment plant purifies wastewater from a paper manufacturing company’s industrial plant, along with wastewater from residents and other wastewater producers in the town and connected villages. A view of the treatment plant premises is given in Fig. 232.

The critical sources of noise on the site of the wastewater treatment plant are the:

- Blower room,
- Air distribution pipes,
- Biofilter,
- Sludge treatment,
- Activation tanks,
- Input pumping station.

Fig. 232 A view of the treatment plant

Description of the Site and Protected Areas

The wastewater treatment plant site is located between two villages. Village A is located at a distance of approximately 200 m north of the treatment plant site, while village B is at a distance of approximately 180 m south of the treatment plant site. The villages contain mainly houses for families. A view of the wastewater treatment plant area and the adjacent villages is shown in Fig. 233.

Fig. 233 A view of the wastewater treatment plant area and the adjacent villages

7.5.3 Knowledge of the Current State of the Noise Situation in the Adjacent Villages

In order to gain knowledge of the current noise situation in the adjacent villages, noise measurements were carried out in both villages in the protected areas near the family homes on the edges of the villages facing toward the wastewater treatment plant. Measurements were made in front of the facade on the family houses. We consider these selected locations to be the most affected by the noise from the plant's operation.

The measurements were carried out in accordance with applicable national legislation and international standards (ISO 1996-1 Acoustics standards. Description, measurement and assessment of environmental noise. Part 1: Basic quantities and assessment procedures; ISO 1996-2 Acoustics. Description, measurement and assessment of environmental noise. Part 2: Determination of sound pressure levels) [173, 174].

The measurement results of the equivalent noise levels are given in Tab. 30. It is clear from the frequency analysis of the noise measurement results that the noise is characterized by tonal components at a frequency of 800 Hz, as shown in Fig. 234.

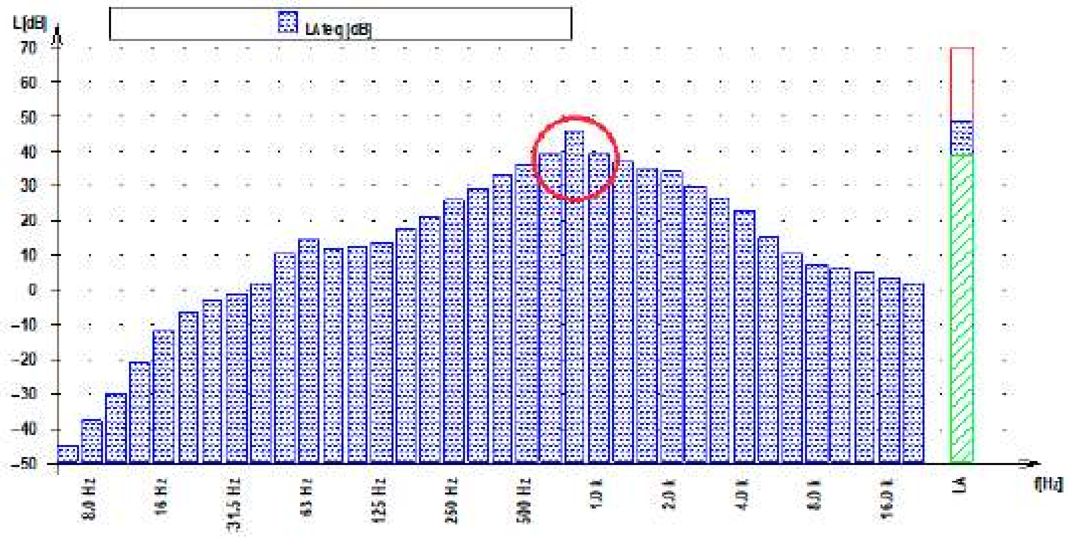


Fig. 234 A weighted 1/3 octave spectrum

From the point of view of the legislation in force, a correction of 5 dB for sound with tonal components should be added to the measured values. Positive values of wide uncertainty must be added to these values. These values can then be compared with the permissible values to determine the noise pollution levels. The results of the noise measurements in the surrounding villages are given in Tab. 30.

Tab. 30

The results of the noise measurements in the surrounding villages

MP	Location of the Measurement Point	Equivalent Sound Pressure Level $L_{Aeq,T}$ [dB]	Correction for Tonal Compound [dB]	Uncertainty [dB]	Assessed Value $L_{R,Aeq,Tref}$ [dB]
P1	Village A, in front of house façade	45,5	5	2,1	52,6
P2	Village B, in front of house facade	52,9	-	2,1	56,0

Based on objectification of the noise measurements, it can be concluded that the noise limit values in both villages are exceeded for all reference intervals: Day, 50 dB(A); evening, 50 dB(A); night, -15 dB(A).

7.5.4 Measurement of the Noise Sources on the Site of the Wastewater Treatment Plant

Measurements on the site of the wastewater treatment plant were carried out: adjacent to the individual noise sources, as well as generally across the site. Measurements were made at 18 measuring points, the locations of which are shown in Fig. 235. The measurement results are shown in Tab. 31.

Fig. 235 The locations of the measuring points on the; site of the wastewater treatment plant

Tab. 31
Measurement results on the site of the wastewater treatment plant

MP	Distance from Source [m]	Location of Measurement Point	$L_{Aeq,T}$ [dB]
M1	6	Blower room - north side	68,1
M2	3	Between blower room and air distribution pipes	79,5
M3	9	Blower room - south side	80,2
M4	6	Activation tanks - south side	68,7
M5	6	Activation tanks - south side	67,5
M6	6	Activation tanks - south side	63,5
M7	6	Activation tanks - south side	59,8
M8	25	Biofilter	62,4
M9	10	Input pumping station	63,6
M10	12	Sludge treatment	63,2
M11	6	Activation tanks - north side	61,8
M12	3	Air distribution pipes	72,3
M13	6	Activation tanks - north side	65,8
M14	3	Air distribution pipes	74,6
M15	3	Air distribution pipes	76,1
M16	6	Northwest border of the wastewater plant	57,1
M17	4	Between blower room and transformer station	64,5
M18	8	Between input pumping station and sludge treatment	66,4

Measurements were carried out to determine the noise level of the stationary sources on the site of the wastewater treatment plant, the results of which were later used as input into the mathematical model (noise map) of the surroundings of the treatment plant, including knowledge of the acoustic situation and the site of the wastewater treatment plant.

7.5.5 Visualization of the Noise Sources on the Site of the Wastewater Treatment Plant

7.5.5.1. Measurement No. 1 - Air Distribution Pipes

Measurement no. 1 was carried out with a focus on the pipes designed for air distribution from a distance of 20 m. Fig. 236 shows a view of the installed acoustic camera. Fig. 237 shows the noise emissions of the visualized object across the 740 – 840 Hz frequency band. The location of the integrated noise source is evident from the acoustic image presented. Fig. 238 shows the noise spectrogram for this measurement. It is clear from the spectrogram that the dominant frequencies are in the range of 740 – 840 Hz.

Fig. 236 View of the installed acoustic camera - measurement No. 1.

Fig. 237 Noise emissions of the visualized object across the frequency band (150 - 13 kHz)—measurement No. 1

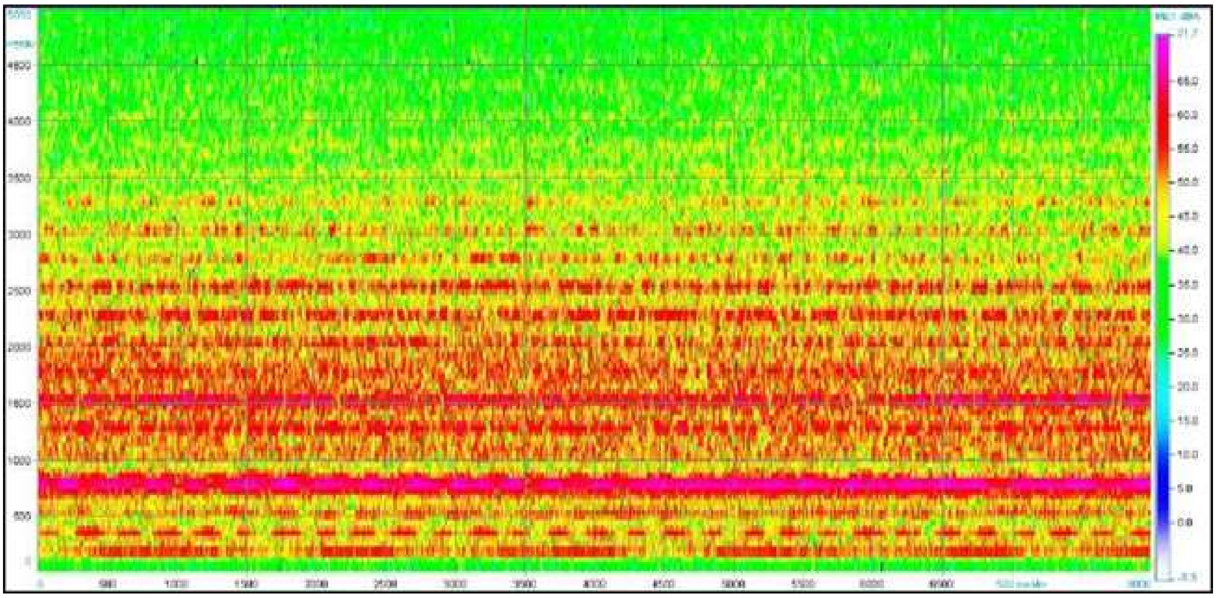


Fig. 238 Spectrogram - measurement No. 1

7.5.5.2. Measurement No. 2 - Blower Room Building (East Side)

Measurement no. 2 was carried out with a focus on the blower room building from the east side from a distance of 13 m. Fig. 239 shows a view of the acoustic camera installed. Fig. 240 shows the noise emissions of the visualized object across the whole frequency band. The location of the integrated noise source is evident from the acoustic image presented. Fig. 241 shows the noise spectrogram for this measurement.

It is clear from the above spectrogram that the dominant frequencies are in the ranges of 250 – 500 and 1500 – 2000 Hz. Fig. 242 shows the noise emissions of the visualized object in the 250 – 500 Hz frequency band, whole Fig. 243 shows the 1500 – 2500 Hz frequency band.

Fig. 239 View of the installed acoustic camera - measurement No. 2

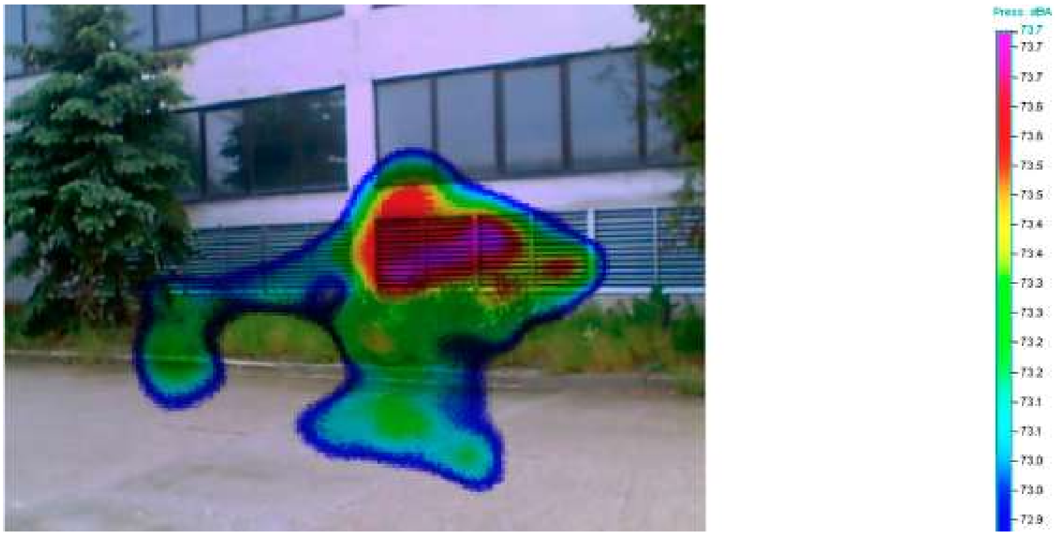


Fig. 240 Noise emissions of the visualized object across the frequency band (150 – 13 kHz) - measurement No. 2.

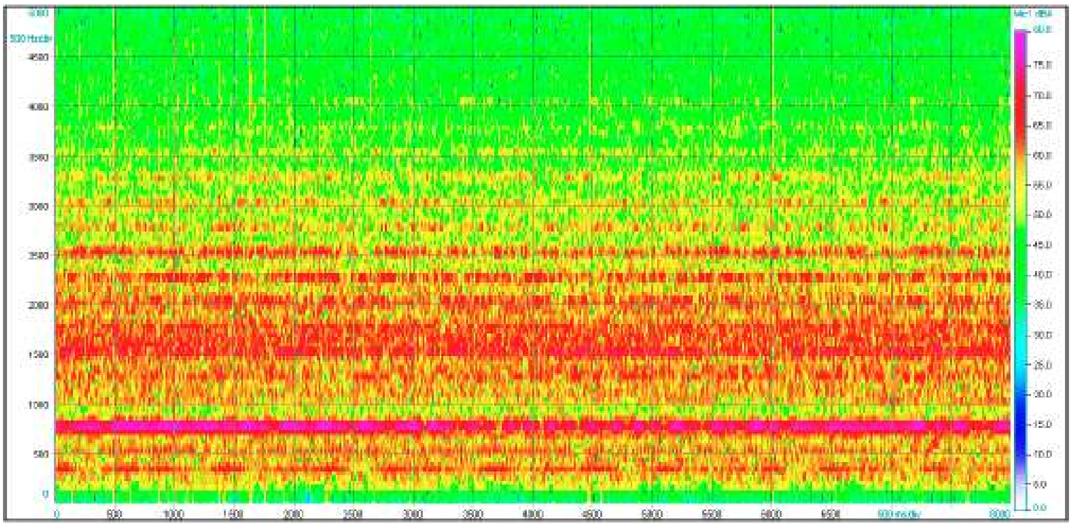


Fig. 241 Spectrogram - measurement No. 2

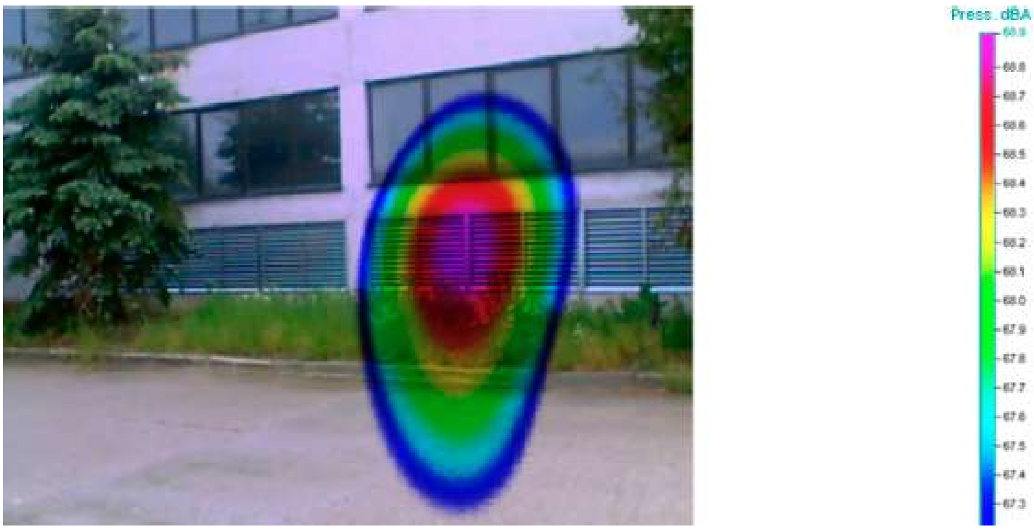


Fig. 242 Noise emissions of the visualized object in the 250 - 500 Hz frequency band - measurement No. 2

Fig. 243 Noise emissions of the visualized object in the 1500 - 2500 Hz frequency band - measurement No. 2

7.5.5.3. Measurement No. 3 - Blower Room Building (South Side)

Measurement No. 3 was carried out with a focus on the blower room building from the south side from a distance of 11 m. Fig. 244 shows the noise emissions of the visualized object across the frequency band. The location of the integrated noise source is evident from the acoustic image presented. Fig. 245 shows the noise spectrogram for this measurement.

Fig. 244 Noise emissions of the visualized object across the frequency band (150 – 13 kHz) - measurement No. 3

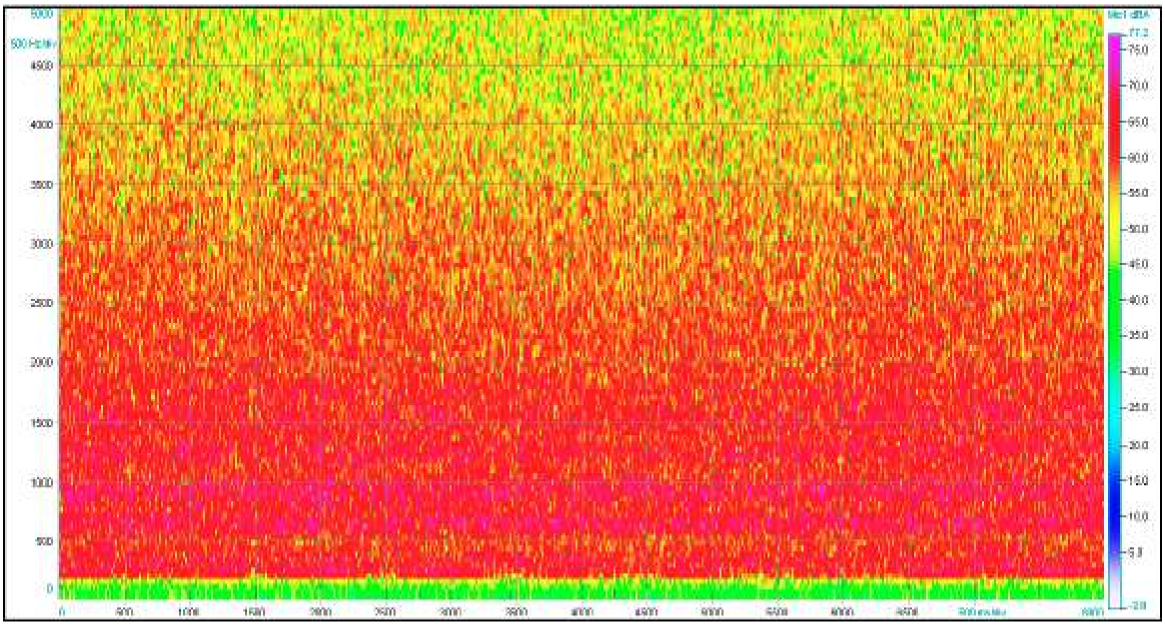


Fig. 245 Spectrogram - measurement No. 3

7.5.5.4. Measurement No. 4 - Sludge Treatment

Measurement No. 4 was carried out with a focus on the object of the sludge farm from a distance of 43 m. Fig. 246 a view of the acoustic camera installed. Fig. 247 shows the noise emissions of the visualized object throughout the frequency band. The location of the integrated noise source is evident from the acoustic image presented. Fig. 248 shows the noise spectrogram of this measurement.

Fig. 246 View of the installed acoustic camera - measurement No. 4.

Fig. 247 Noise emissions of the visualized object across the frequency band (150 - 13 kHz) - measurement No. 4

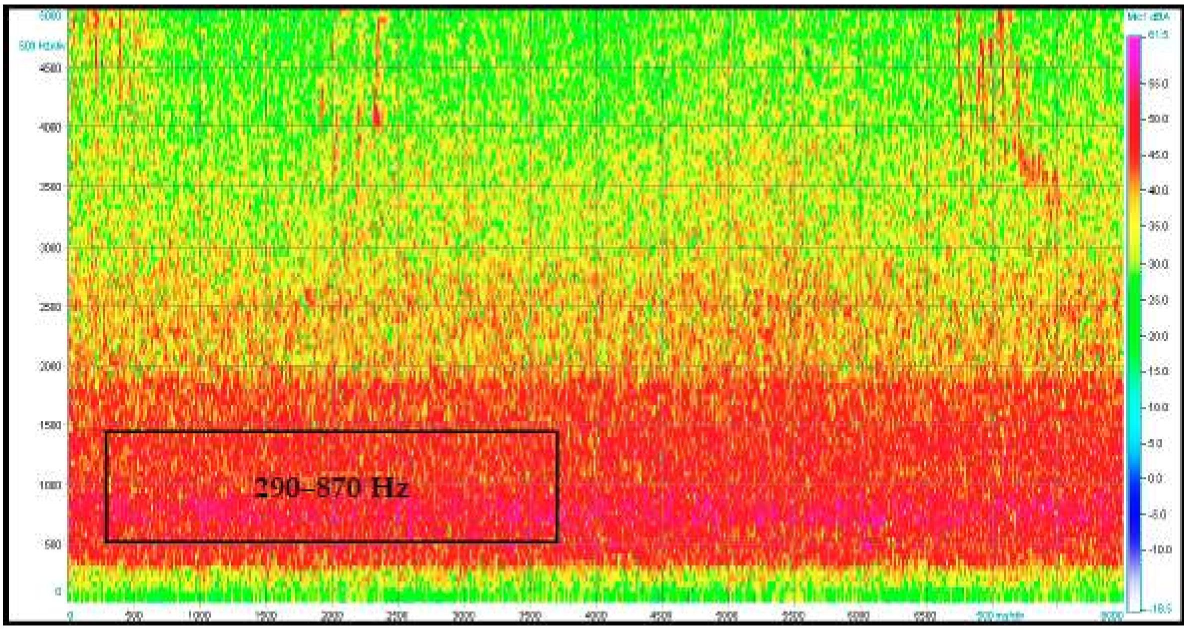


Fig. 248 Spectrogram - measurement No. 4

Based on the measurements taken to visualize the sources of noise of the wastewater treatment plant, the following can be concluded:

- Specific critical points in terms of noise emissions were visualized and identified for individual structures.
- The dominant sources of noise on the WWTP (Waste Water Treatment Plant) site were confirmed to be the:
  - Blower room building,
  - Air distribution pipes,
  - Sludge treatment building.

- The main source of noise in the air distribution pipes was the break in the pipe, where
- noise caused by airflow in the bend occurs.
- Regarding the blower room building, the source of noise was the ventilation openings
- on the south and east.
- The identified noise sources from these objects were confirmed by repeated measurements.
- For the blower room building, the dominant frequency bands were 250 – 500 Hz and
- 1500 – 2500 Hz.
- For the air distribution pipes, the dominant frequency band was 740 – 840 Hz.
- For the sludge treatment building, the dominant frequency band was 290 – 870 Hz.

Knowledge of the dominant frequency bands is important in the selection of appropriate acoustically absorbent materials when implementing noise reduction measures.

7.5.6 Proposal for Measures to Reduce Noise

Based on the noise measurements and the visualizations of noise sources made, the following measures are proposed:

- Acoustic insulation of air distribution pipes
- Replacement of ventilation grilles with acoustic blinds on the blower room and sludge treatment buildings.

7.5.6.1. Acoustic Pipe Insulation

The air distribution line provides air supply to the activation tanks. The air is ducted from the blower room through a pipe with a 1200 mm diameter and a total length of 70 m under a pressure of 60 – 63 kPa and a flow rate of 62 000 – 64 000 m^3/h. Herein, acoustic insulation of the pipe consisted of wrapping the full length of the air distribution pipe with mineral wool with a thickness of 120 mm and a density 60 $kg.m^{-3}$, as well as application of a protective PE (polyethylene) film and an external stainless steel sheet with a thickness of 3 mm. A stainless-steel sheet with a thickness of 3 mm was selected due its good weather resistance, good formability, and good price–performance ratio.

When designing acoustic insulation, it was necessary to take into account the effect of insulation in terms of changing the temperature of the air, which is ducted by pipes into the activation tanks. For this reason, the change in the temperature of the ducted air due to acoustic insulation was calculated. Based on thermodynamic conversion under the given input conditions, the increase in the air temperature in the distribution line was determined to be 2,9 ^{o}C.

After consultation with the operator, it was confirmed that the increase in the temperature of the ducted air would not have negative effects on the operation of the activation tanks. Fig. 249 shows a view of the air distribution pipes before and after application measures to reduce noise.


a) **b)**

Fig. 249 View of the air distribution pipes (a) before and (b) after application measures.

7.5.6.2. Application of Acoustic Blinds

Acoustic blinds were applied to the ventilation openings of the blower room and sludge farm buildings. Standard available acoustic grilles were used, which were made individually as needed. The transmission loss acoustic parameter of the installed acoustic grilles is shown in Tab. 32, only the transmission loss values are indicated, because each acoustic grill is different.

Tab. 32
Transmission loss of the installed acoustic grilles

Frequency [Hz]	63	125	250	500	1000	2000	4000	8000
Transmission Loss [dB]	2	3	3	5	7	11	13	18

Fig. 250 shows a view of the blower room before and after application measures to reduce noise.


a) **b)**

Fig. 250 View of blower room a) before and b) after application measures

7.5.7 Creating a Mathematical Model-Based Noise Map

The mathematical model was created using the CADNA A version 3.6.117 software package with the relevant methodologies implemented. Noise maps were created for both the current situation and as a prediction of the implemented measures to reduce noise.

The noise map of the current situation was created to understand the current noise situation in the area in question. The prediction noise map was created to verify the efficiency of the proposed adjustments to reduce noise and their impact on the distribution of sound to the surrounding environment.

In creating the analytical noise map of the equivalent noise levels in the external environment of the area of interest from the emissions of acoustic energy from the stationary industrial noise sources situated on the site of the wastewater treatment plant, the general principle of breaking down the phenomenon under consideration (i.e., noise emitted by an industrial source) to elementary phenomena was used, followed by synthesizing the effects of individual elementary phenomena at the site under consideration.

The noise maps created address the problem of the impact of noise from the operation of the wastewater treatment plant on the surrounding area. When creating the noise maps, we took into account all of the stationary noise sources contingent on the operation of the wastewater treatment plant.

The input data about sound power levels of sound sources that were used in mathematical model are presented in Tab. 33.

Tab. 33
Sound power level of sound sources

Source	Type	Sound Power Level [dB]	
		Before	After
Blower room - north	Point	94	85
Blower room - south	Point	85	80
Air distribution pipe - knee	Point	100	87
Air distribution pipe	Line	70 - 80	60 - 70
Biofilter	Point	80	80
Sludge treatment	Point	85	80
Activation tanks	Point	65	65

To get an idea of noise emissions around the wastewater treatment plant, we present values of the equivalent noise level at some calculation points in Tab. 34. The values relate to a distance of 1,5 m in front of the outer walls, where the calculation points were situated next to buildings. The positions of the calculation points are shown in Fig. 251.

Noise maps were created with noise isophones at a height of 1,5 or 3 m above ground level, which were then color coded in 5 dB steps. The height of the isophone and calculation points was chosen as 3 m because of the hilly terrain, in aid of better knowledge of the acoustic situation and the spread of noise at the location in question, and also because a large number of the houses have windows at this height.

Both types of noise maps were designed for the reference time intervals of day, evening, and night, in accordance with the relevant legislation, since the stationary noise sources are constant during these reference time intervals, there is no basis to create noise maps individually for these reference time intervals.

A noise map of the current situation is shown in Fig. 252, and a noise map prediction with the proposed measures to reduce noise is shown in Fig. 253.

Fig. 251 The positions of the calculation points

Tab. 34
The calculated values of the sound pressure levels at the calculation points (CP1 - CP7)

CP	Measurement Point	Height above Ground [m]	Equivalent Sound Pressure Level	Equivalent Sound Pressure Level
			L_{Aeq} [dB]	L_{Aeq} [dB]
			Current Situation	Prediction
			Day Evening Night	Day Evening Night
CP1	Village A, house facade	1,5	46,5	39,4
		3	49,2	42,2
CP2	Village A, kindergarten building facade	1,5	47,5	40,1
		3	50,1	42,8
CP3	Village A, house facade	1,5	48,6	41,3
		3	51,3	44,3
CP4	Village A, east part	1,5	45,7	41,0
		3	48,7	43,0
CP5	Village B, house facade	1,5	47,3	43,0
		3	51,2	46,4
CP6	North border of WWTP	1,5	64,5	54,4
		3	-	56,2
CP7	South border of WWTP	1,5	57,5	49,5
		3	-	53,0

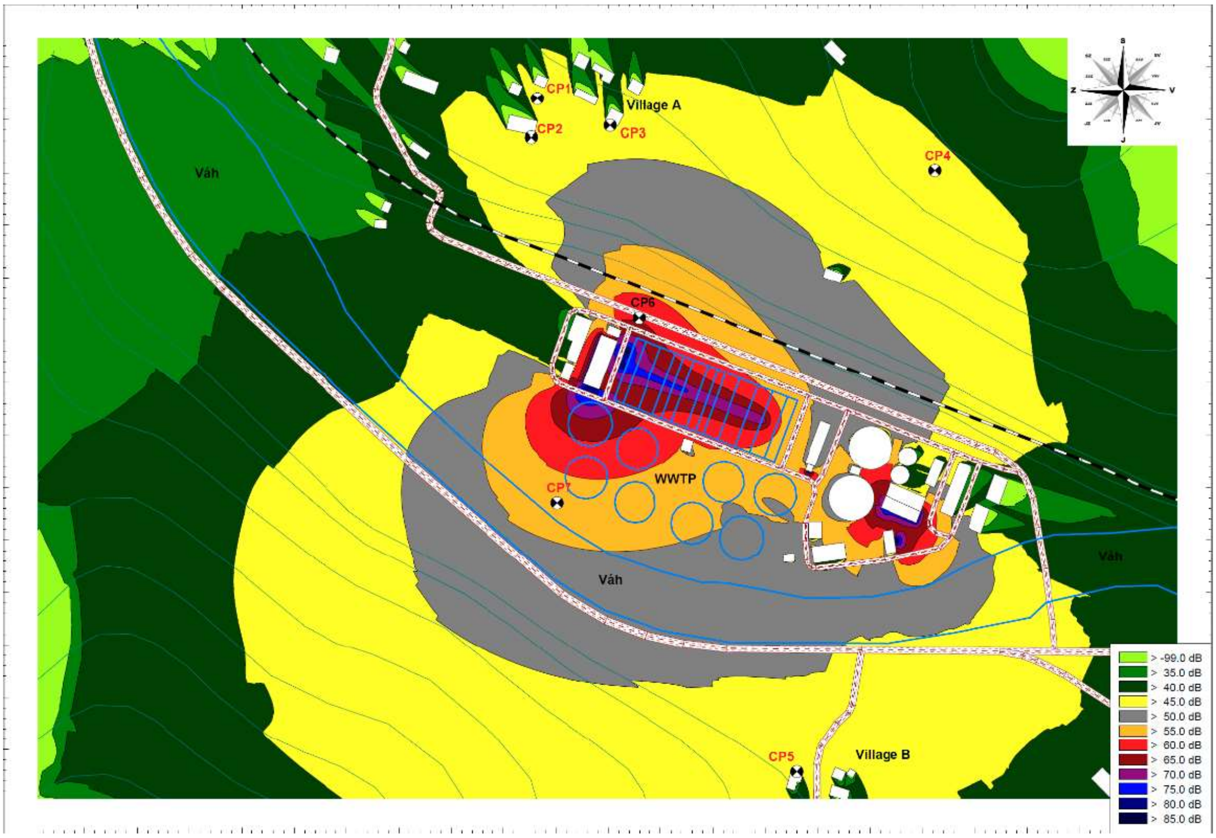


Fig. 252 Noise map of the current situation (before application of measures)

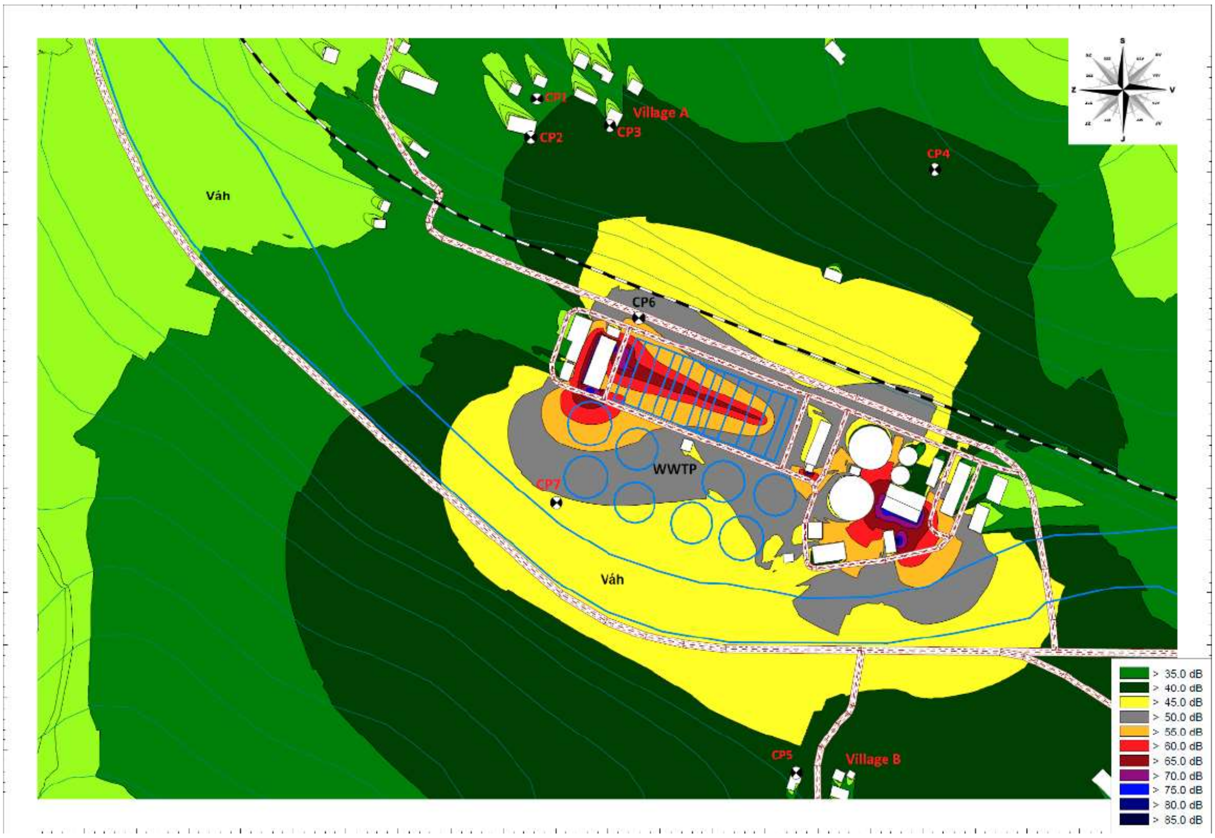


Fig. 253 Noise map prediction (application of noise reduction measures)

7.5.8 Verification of the Effectiveness of the Measures Implemented

The proposed noise reduction measures were carried out at the wastewater treatment plant. After the measures were put into practice, further measurements were made to assess the effectiveness of the measures taken. The measurements were performed on the premises of the wastewater treatment plant and in both villages where the permissible values were exceeded. All measurements were made at identical locations to those from before the measures were implemented.

The results of measurements at the wastewater treatment plant site before and after the measures are presented in Tab. 35.

Tab. 35

Results of measurements at the wastewater treatment plant site before and after the measures

MP	Distance from Source [m]	Location of the Measurement Point	$L_{Aeq,T}$ [dB]	
			Before	After
M1	6	Blower room - north side	68,1	58,7
M2	3	Between blower room and air distribution pipes	79,5	64,5
M3	9	Blower room - south side	80,2	66,0
M4	6	Activation tanks - south side	68,7	60,1
M5	6	Activation tanks - south side	67,5	61,4
M6	6	Activation tanks - south side	63,5	60,2
M7	6	Activation tanks - south side	59,8	59,0
M8	25	Biofilter	62,4	58,4
M9	10	Input pumping station	63,6	62,4
M10	12	Sludge treatment	63,2	52,4
M11	6	Activation tanks - north side	61,8	54,4
M12	3	Air distribution pipes	72,3	65,4
M13	6	Activation tanks - north side	65,8	54,8
M14	3	Air distribution pipes	74,6	73,1
M15	3	Air distribution pipes	76,1	67,3
M16	6	Northwest border of wastewater plant	57,1	56,2
M17	4	Between blower room and transformer station	64,5	63,5
M18	8	Between input pumping station and sludge treatment	66,4	59,1

The results of the measurements of the equivalent noise levels in both villages before and after the noise reduction measures were implemented are given in Tab. 36. It is clear from the frequency analysis of the results of the noise measurement that the nature of the noise after the measures were taken did not contain tonal components; therefore, it was not necessary to apply a correction of 5 dB for sound with tonal components to the measured values. Positive values of wide uncertainty must be added to these values. The values can then be compared with the permissible values determining the noise levels.

It is clear from the measured values on the site of the wastewater treatment plant that, after the noise reduction measures were implemented, equivalent levels of A sound pressure were reduced at all measured locations. The reduction in noise levels was between 0,8 and

15,0 dB. In places where critical noise sources were identified, the reduction in noise levels was between 8,8 and 15 dB.

Based on the measured values at the treatment plant site and in the adjacent villages, we can conclude the modifications made to reduce noise were highly effective.

Tab. 36

Results of measurements in both villages before and after the noise reduction measures

MP	Location of the Measurement Point	Equivalent Sound Pressure Level $L_{Aeq,T}$ [dB]		Correction for Tonal Compound [dB]		Uncertainty [dB]	Assessed Value $L_{R,Aeq,Tref}$ [dB]	
		Before	After	Before	After		Before	After
P1	Village A, in front house facade	45,5	40,1	5	-	2,1	52,6	42,2
P2	Village B, in front of house facade	52,9	47,5	-	-		56,0	49,6

The issue of noise reduction of industrial plants is an important task, considering the increasing numbers of these sources. A significant number of industrial noise sources are located near people's residences. It is estimated that around 800 000 people, living in urban areas in the European Union, are exposed to industry noise levels of at least 55 dB during the day evening - night period and around 400 000 to levels of at least 50 dB during the night-time period. [178] With the increasing numbers of industrial noise sources, people are increasingly exposed to excessive noise, which is closely linked to negative effects on human health and a reduction in the quality of their housing [178].

Reducing the noise from industrial sources and their impact on people requires a comprehensive approach. The basis is insight in of the current state of the acoustic situation using special measuring instruments. Based on these measurements, herein, critical noise sources were identified on the site of the wastewater treatment plant. The dominant sources of noise were identified as being mainly the blower room and air distribution pipes.

With thorough information-gathering, specific proposals, and measures can be taken to reduce the noise from sources in order to reduce the negative impact on people in the vicinity. Before implementing these measures, it is appropriate to model and simulate these measures and to assess their effectiveness on a preliminary basis, and making possible corrections if necessary. The next step is to then thoroughly implement the proposed measures in accordance with the technical proposal. The final step is to verify the effectiveness of the proposed noise measures, to compare them with the original situation and the model created.

In this case study, all of the above steps were taken to reduce the negative noise effects of the wastewater treatment plant on the people in the vicinity. After defining the problem in order to understand the current state of the noise situation, noise measurements were carried out in adjacent villages and directly in the area the wastewater treatment plant site.

It was clear from the measurements that the permissible noise levels in these municipalities were being exceeded due to the wastewater treatment plant. Measurements directly at the wastewater treatment plant were carried out in order to identify the partial noise sources. For more accurate analysis, a unique tool for visualizing noise was used, namely, an acoustic camera. On the basis of these measurements, the dominant noise sources were identified on the wastewater treatment plant site. Subsequently, a proposal was made to reduce the noise of the dominant noise sources, and mathematical models were created for a preliminary assessment of the efficiency - i.e., noise maps of the current state and a predictive noise map simulated with the measures. On the basis of these noise maps, it was predicted that the above proposals would contribute to reducing noise in the surrounding villages.

After the implementation of the proposed measures, noise measurements were again performed in adjacent municipalities and in the area of the wastewater treatment plant. It is clear from the noise measurements that after the measures were implemented, there was a significant reduction in noise in the surrounding villages, as well as directly in the wastewater treatment plant.

The measured values in the surrounding villages also showed a decrease in equivalent levels of A sound pressure. In Village 1, there was a decrease of 5,4 dB and the tonal component of the sound was also removed, so it was not necessary to apply a correction of +5 dB. In Village 2, equivalent levels of A sound pressure were reduced by 6,4 dB. In conclusion, the proposed measures were highly effective, with a significant reduction in the noise in nearby people's homes, thereby significantly increasing the quality of life for these people and reducing the negative impacts on their health.

By applying the above steps in this case study in order to reduce the negative impact and to correctly implement the proposed measures to reduce noise from industrial sources, a reduction in noise based on this model can also be achieved for other industrial sources of a similar nature.

8 BASIC COMPONENTS OF THE ENVIRONMENT - SOIL

Soil is considered as one of the most precious treasures of humanity that allows plants, animals and humans live on Earth. Soil is the product of millennial development. Space that fills the land called pedosphere. Pedosphere has major impact on other geosphere - the atmosphere, hydrosphere and lithosphere (Fig. 254). [2]

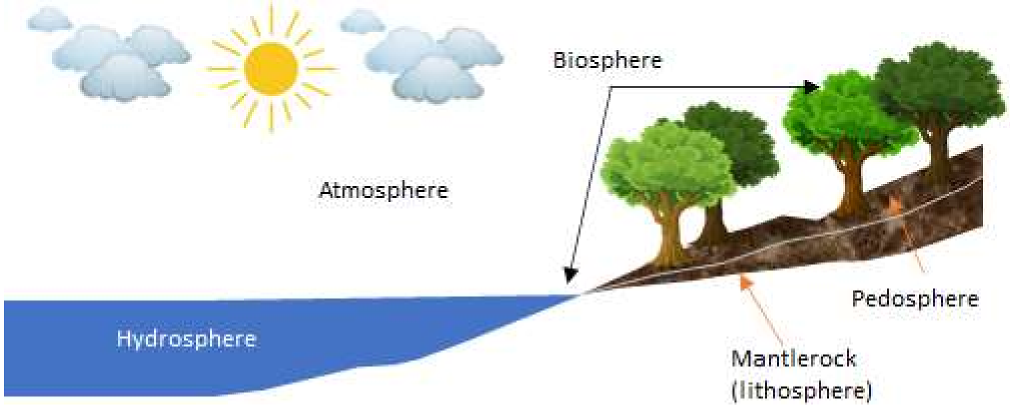


Fig. 254 Location of land between the geosphere

Soil is an independent natural formation, created by transforming the upper part of the Earth's crust by the action of organisms on the rocks, with the participation of water, air and solar energy. It is a surface layer of thickness 0,2 to 3,0 m [142]. Soil is the result of many years of development, since the decay and weathering processes are slow. In our geological and climatic proportions, it occurs on average for 300 years soil layer with a thickness of 1 cm [179]. For this reason, the soil is practically irreplaceable natural wealth. Studies of soils are interested in the subject of a separate science - **Soil Science**. [11]

8.1 Soil

Soil is a natural body laced with distinctive dynamics of physical, chemical, biochemical and microbial processes and is characterized by a wedded stratigraphy, i.e. layering and production potential. [30]

8.1.1 Soil Formation

Soil [4] is characterized by high dynamics of the physical, chemical, biochemical and microbiological processes, and is characterized by the wedded stratigraphy. It is in constant interaction with other components of the environment - creates, develops, care. The soil is formed during geological times by the action of physical and chemical factors lifeless nature and effects of the living organism to the parent rock. By origin, there are three **basic types of parent rock** [4]:

- **igneous,**
- **sedimentary rocks,**
- **metamorphics rocks.**

Soil formation processes

By the influence of soil-forming processes, the surface layers of rock effloresce, disrupted by debris and take away by the wind and water. The various types of rock are mixed, enriching the elements that they were missing and the change their physical and chemical properties. By parent rock is created life-giving soil. [6]

For the formation of the soil, it is also important interaction of soil-forming factors, among which include [7]:

- **climate,**
- **groundwater,**
- **relief of the country,**
- **the impact of vegetation and living organisms,**
- **men.**

8.1.2 Soil Structure

Soil (Fig. 255) is not only just any natural formation. It has its configuration - its structure. It is based - as in the living body - skeleton. It consists of large particles around, which are grouped smaller and quite small grains and grains wide variety of shapes. [180]

Fig. 255 Soil [181]

In general, the soil can be divided into two types [180]:

- **non-structural** - dominated the smallest particles, for example. sand,
- **structural** - in it dominate soil average grain size.

The structured soils are free spaces most varied size and shape - soil pores. Some pores, the air, the water in the other. To penetrate the pores of the soil seed plant, where the roots take hold and flush. Here even the smallest living creatures reviving soil. The number and size of the pores affect the soil permeability and aeration of the soil. The soil has a better structure; the greater is its **permeability** (permeability). [180]

The pores of the soil and the air accumulates, which is printed in the soil after the high barometric pressure, in it to become clogged with the water or into the slowly **diffuses** (penetrating) from the outside. The air content in the soil expresses the concept of **unsaturated soil**. [180]

The surface layers of the soil, the air in soil pores almost does not differ from the atmospheric air, but the deeper we penetrate, the less oxygen is found in the soil air and it is there more carbon dioxide. Therefore, the most active life is in the surface layers of the soil. Small mammals live here, most diverse worms and beetles and mainly billions of microbes, without which the land had been dead and unfruitful. Larger animals, worms and insects, jar and loosen the soil and thus allow air to penetrate into the deeper layers. Decreases with increasing depth of life-giving oxygen and the living creatures are less. At a depth of about **six meters** generally we not replicated any microorganisms. [180]

For all the living organisms present in the soil, scientists are generated the name - **edafon (soil organism's)**. The most fertile land component of the top layer is **humus**. It is produced by decay of fallen leaves and dead bodies of plants and animals. These are the primary - the primary component of humus. They feed on soil micro-organisms, which break down and transform while dead tissue to the large molecules of humic acid, fulvic acid and partly to the parent compounds and elements. Going to take place in the formation of humus call - it means huminification.

8.1.3 Soil Water

Water [30] exists in soil in the triple form. **Soil water adsorption** firmly adheres to the surface of soil grains, bound by their electrostatic forces. It is an integral part of the soil grains and plants or animals cannot use it. **Capillary water** is present in not structures land, where is the very slight grains, there are no soil pores, but only very fine capillary slot. The water here flows in any direction, it always faces the flow from damp places to a dry place. The structural soil with pores larger than 0,1 mm from the surface of the water flows down, to submit to the laws of gravity. Therefore, we called gravitational water (Fig. 256). [182]

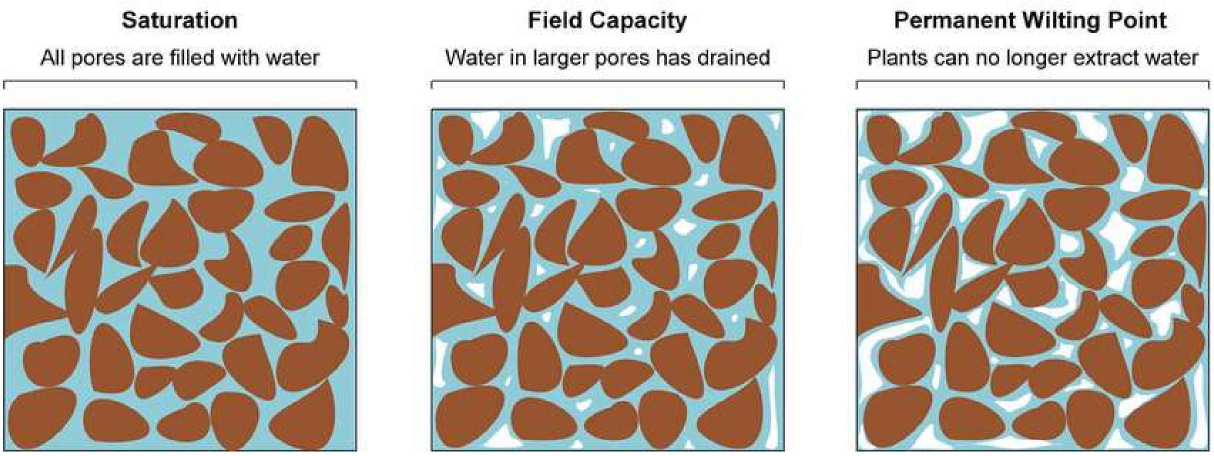


Fig. 256 Soil water [182]

8.2 Soil Characteristics

In this part of the chapter will focus on soil properties and land distribution.

8.2.1 Soil Properties

In terms of material composition of the soil can be [3] generally characterized as a heterogeneous, multi-component, which consists of solid, liquid and gas phase. The solid phase is composed of mineral and organic fraction, a liquid phase comprising an aqueous solution and gas phase soil air. [142] Representation of these components varies, depending for example the type of soil and on its moistening. [179]

From a theoretical and practical point of view, soil characteristics broken down into [179]:

- chemical,
- physical,
- biological.

8.2.1.1. Chemical Properties of the Soil

Chemical properties of the soil can be assessed through the relatively complex nature of the reactions occurring mainly between soil solution and colloidal part of the land and the soil and root system of plants. [183] The basic properties include [183]:

- **soil reaction** - one of the most important properties of the soil is also pH value (Tab. 37). Soil reaction affects the solubility of the substances in the soil, and thus the usability of live organisms, accessibility of nutrients, adsorption and desorption of cations, biochemical reactions, the soil structure and thus the physical properties.

Tab. 37
Evaluation of pH soil

pH/H_2O	Guest
> 3,5	very acidic
3,5-4,4	extremely acid
4,5-5,0	very strongly acidic
5,1-5,5	strongly acid
6,1-6,5	slightly acidic
6,6-7,3	neutral
7,4-7,8	slightly alkaline
7,9-8,4	moderately alkaline
8,5-9,	strongly alkaline
> 9,0	very strongly alkaline

The increased acidity of the soil reduces the solubility of many substances (e.g. compounds of Ca, Mg, K, Na and the like), sometimes under the living minimum of plants. The utility of the phosphoric acid is optimal at a pH of soil from 6,5 to 7,5.

Soil acidity worsens the living conditions for soil organisms. Most of them needs for its development of a neutral environment.

On most parts of the Slovak Republic prevails acidic soil, slightly acidic to neutral soil reaction (pH from 4,5 to 7,3) even when the acidity of the soil due to environmental pollution (particularly carbon dioxide) in many places has increased significantly. Adverse developments in acidification of soils has resulted that in about 700 000 ha of agricultural lands show a reaction below pH 5,5.

In addition, strongly acidic soil reaction is recorded at the highest positions - up to pH 4,5. In the Danube lowland is strong alkaline soil reaction - above pH 7,3.

- **sorption capacity and the sorption complex character** - the ability to land attracts ions, molecules of various substances, called the sorption capacity of the soil. We know of several mechanisms of sorption: mechanical, physical - chemical, chemical and biological.
- **chemical composition of mineral land share** - the ratio of inorganic to organic matter in most soils can say about the relationship 10 : 1. The soil containing the most oxygen (about 50 %) and silicon (about 25 %), from the other elements is mainly aluminium (clay), iron, calcium (gypsum), sodium, potassium (K), magnesium, hydrogen, titanium, to be in significantly less carbon, chlorine, phosphorus (P), sulphur and manganese (Mg) - (Tab. 38).
- **organic fraction of soil (humus content and qualitative composition)** - organic matter in the soil is an essential part of the soil. We understand by it dead bodies of plants and animals and with the original anatomical structure and humus.

Tab. 38

Nutrient content given in % of the total land area in Slovakia

Nutrient	P	K	Mg
Very low	7,1	1,6	0,4
Low	11,0	8,6	1,7
Middle	33,9	25,0	8,0
Good	13,4	34,5	17,0

Humus is a complex, dynamic complex of organic compounds, which are created the degradation and humification of organic matter in the soil. The organic portion of soil (in addition to living organisms) is in the form of humus. Evaluation of contents of coal, humus and humus horizons is shown in the Tab. 39. [183]

Tab. 39

Evaluation of the carbon contents and humus horizons

Carbon content (% Cox)	Humus content %	Guest	
		Content in %	Humus term
< 0,6	< 1	Very low	Slightly humic
0,6 - 1,7	1,0 - 1,9	Low	Slightly humous
1,2 - 1,7	2,0 - 2,9	Middle	Medium humic
1,8 - 2,9	3,0 - 5,0	Good	Strongly humic
> 2,9	> 5,0	Very high	Very strongly humic

8.2.1.2. The Physical Properties of Soil

We called physical properties of soil that one's, which can evaluate visually or by finger. Soil is a porous body having specific physical properties. These include structure, porosity, power of soil profile or horizons and colour.

The basic physical properties include [182]:

- **specific weight,**
- **grit,**
- **density,**
- **structure of land,**
- **soil porosity.**

8.2.1.3. Biological Properties of Soil

The basic biological properties of the soil include [183]:

- **mineralization of soil organic matter** - the activity of microorganisms by measuring of the amount of carbon dioxide released from the soil. Natural processes of the release of carbon dioxide provides the necessary carbon cycle in nature,
- **soil nitrogen mineralization** - the process of release of mineral forms of nitrogen from soil organic matter,
- **nitrification** - the biological oxidation of mineral nitrogen in the soil.

8.2.1.4. Some Functional Properties of the Soil

Some functional properties of the soil [182]:

- **airiness (aeration) of land** - is an important thing for the progress of self-cleaning process in the soil,
- **soil temperature** - the source is sunlight, hot core of the earth, and to some extent also biochemical processes occurring in the soil. The temperature of the soil also varies with depth. Thermal conditions of the soil are one of the factors that affect the biochemical processes occurring in the soil.

8.2.1.5. Fertility and Productive Capacity of the Soil

Soil fertility includes its ability to provide conditions for plants and other organisms for which is the land environment. It is the result of complex action of physical, chemical and biological properties and the different processes occurring in the soil. [2]

The production capacity of the soil - is understood as a measurable degree of basic attributes of a particular land to take, to transform, to accumulate and to pass the required amount of water, nutrients and energy for growth and production of plants. In terms of biological, ecological and growing, in principle, we identify the three levels of production [11]:

- **theoretically possible production,**

- **potential production,**
- **real production.**

8.2.2 Allocation of Land

Soil can be classified according to various criteria [109]. Under prevailing particulate matter and total soil texture is divided into the following types of soil [179]:

- **light soil**: sandy soil,
- **medium heavy soil:** clay soil,
- **heavy soils:** clay soils.

Under the conditions of arise, mainly determined by the parent rock on which arises, it is characterized by its **soil profile**. Under the soil profile we mean a vertical cross-section, which consists of several soil **horizons**. [109]

Soil horizon is a layer of identical external changes as well as physical and chemical characteristics and composition.

The various horizons are marked with the letters of the alphabet (Fig. 257):

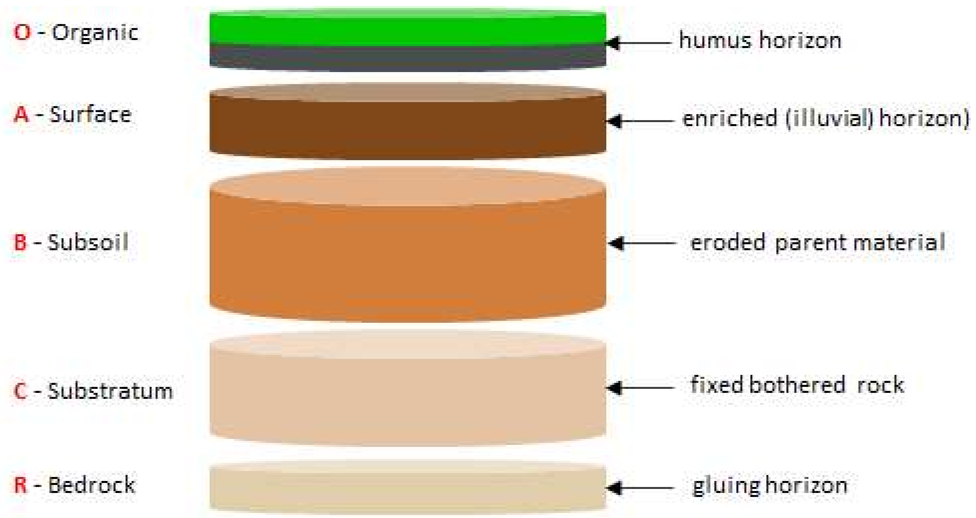


Fig. 257 The soil profile

Commonly we distinguish the following **soil types** [109]:

- **red-yellow soils,**
- **red soil of savannas,**
- **desert land/ soils,**
- **yellow earth and red earth,**
- **chestnut soils,**
- **black soils,**
- **brown earth,**

- **ilimerized soils,**
- **brown soils,**
- **soil of mountains with cool and rain climate,**
- **tundra soil.**

8.3 Self-cleaning of Soil

Soil like air, forest, various flora and fauna - belongs to one of the natural renewable resources. [3] The time needed to rebuild is varies, but always depends on the condition and quality of what is being renewed. [179]

With the water permeate into the soil the most diverse contaminants [8]. If they have accumulated in the soil and they would have smothered any life and soil would has been perish. This prevents self-cleaning capacity of the soil.

Progress of the **soil self-cleaning** consists of the following processes [9]:

- **filtration,**
- **absorption,**
- **chemical and biological action of the soil,**
- **mineralization,**
- **decomposition**
- **microorganisms.**

The basic condition for self-cleaning of soil is sufficient oxygen and favourable pH of soil. Self-cleaning (Fig. 258) starts with the soil pores, which serve as a **filter**. After filtration follows **absorption**, in which the soil grains consume next materials. The soil is well absorbed proteins and substances resulting from their degradation. But non-organic substances do not penetrate the soil. Between the soil and the extraneous substances run complex **chemical reactions**. Ions of substances, which are dissolved in the water, are combined together with an oppositely charged ion in the soil and form inorganic compounds, which are the final products of digestion. The **mineralization** occurs in the deeper layers of soil. During the mineralization is many stages, which could not be made without the active participation of the soil organisms. The organics substances decompose to the basic elements that react with some substances in the soil, so they will produce a final inorganic compound. [3]

Decomposition is started by the most diverse beetles, worms and insect larvae, which destroy dead bodies, and thus prepare the soil for the next phase of decomposition, whose main actors are soil **microorganisms**. [179]

Other microorganisms ferment sugars, others break down the fats into glycerol and fatty acids, of which by the other chemical processes is formed the water and CO_2. **If the waste is too much, self-cleaning capacity of the soil is exhausted.** [179]

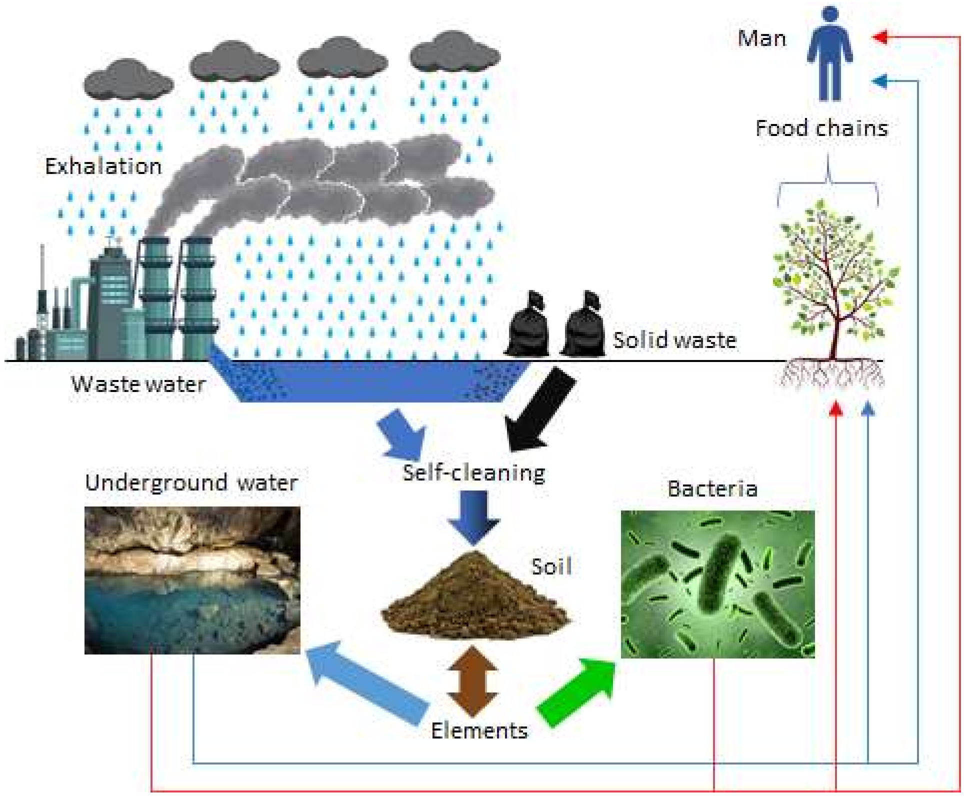


Fig. 258 Self-cleaning process of soil

8.4 Degradation (Polluting) of Soil

Pollution has a relatively permanent or long-term character. We cannot sense it by the sense organs in the form of odour or by change of taste characteristics. It is manifested in hidden form and therefore the initial stages of pollution are difficult to control. Pollution of soil is indirect in most cases and is usually preceded by air or water pollution. Pollution is **devastation** and **degradation**, and ultimately it is the **reduction of production and deterioration of soil quality.** [179]

The devastation of soil is the intervention of natural phenomena (floods, earthquakes) or human, when is threatened the own substance/ nature of the country and its next utilisation is possible only after complex biochemical measures. [3]

Soil degradation is the deterioration of soil properties. It is a process that reduces the ability of soil to form a crop, eco-operate and provide services.

There are three main methods of soil degradation [183]:

- **physical degradation** (e.g. water erosion, wind erosion, soil compaction, soil waterlogging, desertification, landslides),
- **chemical degradation** (acidification respectively. Alkalinisation of the soil, soil salinization, reducing the amount and quality of humus in the soil, reduce the nutrient content in the soil, soil contamination by heavy metals and organic compounds),

- **biological degradation** (presence of animals in the soil, mineralization of soil organic matter, nitrogen mineralization, nitrification).

The intensity of soil degradation can be [179]:

- **low,** when they are slightly reduced productive and ecological functions of soil with possible remedies by commonly used in land management,
- **mean,** when reduced productive and ecological functions of soil and correction is possible by investment improver measures,
- **strong,** when is loss the productive and ecological functions of soil, with the possibility of renewal,
- **extreme**, when it occurs an irreversible loss of productive and ecological functions of soil.

8.4.1 Physical Soil Degradation

Soil degradation is irreversible or slowly reversible damage of physical, mechanical, technological and profile properties of soils. **Physical degradation** of soil in our conditions causes [183]:

- water erosion,
- wind erosion,
- soil compaction,
- water-logging of the soil.

Factors of water erosion [183]**:**

- climatic and hydrological (geographical location, altitude, quantity and intensity precipitation, surface runoff, temperature, evaporation),
- morphology (slope topography, length and shape of the slope, exposure),
- vegetation (density and height of vegetation cover),
- manner of use and land management (position and shape of the plot, direction and machining technology, crop rotation).

Factors wind erosion [183]**:**

- climate (intensity, direction, frequency of winds, humidity area),
- soil (structure and type of soil, soil surface roughness, soil moisture),
- morphological (orientation to the prevailing winds),
- vegetation (length and density of vegetation cover),
- methods of soil management (forest land to the direction of prevailing winds
- methods of cultivation, without tillage sowing, crop rotation, height differences).

Soil compaction

Compaction of soil is an important process of soil degradation, which affected the production function of soil as well as its susceptibility to other degradation processes of soil and landscape (soil erosion, floods).

It recognizes [183]:

- **Primary compaction** - determined by genetically characteristics of the soil, where suffered all the heavy soils (pseudogleys, luvisols).
- **Secondary (technogenous) compaction** - caused by human activities.

Soil compaction (topsoil, subsoil) can have the following effects [183]:

- worse nourished plants, crops are incomplete, rooting depth is shallower and the roots are distortions,
- reduces infiltration into the soil profile and the retention capacity of soils,
- limits the penetration of air into the soil and soil air exchange,
- reduces biological activity of soils,
- reduces soil fertility and ecological functions of soil.

For these reasons, it is important to minimize soil compaction. The fertilization of the excessively compacted soil is expensive and lengthy.

Waterlogging of land

Agricultural soils of Slovakia are in certain locations permanently affected by a high water level (the area of about 560 000 ha), of which in conjunction with the unfavourable grain composition (high content of clay particles) implies a less favourable structure of soil susceptibility to compaction; a low water permeability. Entrance to these sites is time-delays. The most extensive areas of such soil are in the area of the Eastern lowlands.

The basic step for the treatment of the water regime of waterlogged soil is draining, and of dried soils is irrigation; at the same time it is used by other agro-technical interventions.

Drainage of the soil has a great influence on the development of the soil only in terms of water regime, but also in terms of its mechanical composition and physical state, which provides suitable conditions for the creation of structural soil, which is important for the development of crop plants.

The detailed analysis of the possibilities of dewatering occur limiting factors for which we have, in some cases excluded from waterlogged land drainage design. They are mainly temporal, economic and technical factors. **Soil drainage is considered one of the most effective investments in agriculture.** [182]

8.4.2 Chemical Soil Degradation

Chemical degradation of soils can be caused by hazardous inorganic and organic nature of natural and anthropogenic sources, which in a certain concentration to be harmful to the soil causes changes in the physical, chemical and biological properties adversely affect the production potential of soils, reduce nutritional, technological and sensory the value of the crop, and negative effects on the water, the atmosphere, as well as human and animal health.

Serious chemical degradation include [184]:

- acidification of soils,
- alkalinisation and salinization of soils,
- reduction of the quantity and quality of humus in the soil,
- reduction of nutrients in soil and soil solution,
- contamination of soils with heavy metals,
- contamination of soils with organic pollutants.

Soil acidification

Soil reaction is an important parameter for assessing the potential of productive and ecological functions of soil. We express it pH values. The following guidance applies suitability of agricultural lands for their use in terms of soil pH values (Fig. 259):

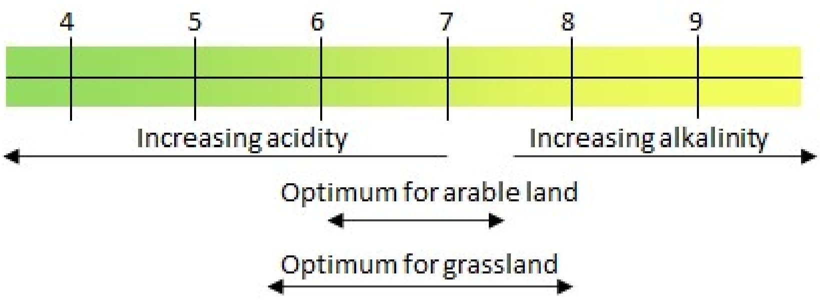


Fig. 259 Scheme of use of agricultural soil due to soil pH [2]

For these reasons, it is essential to maintain the optimum pH, i.e., permanently alter the unfavourable soil reaction. [11]

Soil pH is a way of expressing the acidity respectively alkalinity. Soil with a pH of 7 is neutral. Towards lower pH increases the acidity of the soil, at a pH greater than 7 increases alkalinity. Soil reaction affects the solubility of the substances in the soil, and thus the usability of live organisms, accessibility of nutrients, adsorption and desorption of cations, biochemical reactions, the soil structure and thus the physical properties. [184]

Alkalinisation and salinization of soils

The opposite is the acidification of soil is **salinization and alkalization**, i.e. increasing levels of soil reaction. It may take place gradually in the natural evolution of the soils in the subsoil, where they occur strongly mineralized water, but most intensively this process can occur secondarily, the effect of alkali emissions and waste. [184]

The current developments taking place in our lowlands, not only highlights the increasing mineralization of groundwater levels and its height, which is the main cause of **saline soils** and development, but there is also a gradual global warming, which increases evaporation and accumulation of salts in the soil from rising groundwater. It is therefore no realistic prospect of gradual expansion of saline soils. This is all the more important that salinization and alkalization of soils greatly reduces soil fertility. [2]

Saline soils are soils, which contain salts of sodium with the ion reaches the amount that is harmful to the growth of most plants. A detailed study of these soils, especially the study of the chemical nature of the sodium salt present (neutral, alkaline), and their effect on a range of plants, and the chemical and physical properties of the soil, a distinction between the two main groups of saline soils [184]:

- **alkaline soils**, contain hydrolysable alkaline salts, especially carbonate, bicarbonate, and sodium silicate,
- **saline soils** or saline soils, containing neutral sodium salts (chloride and sulphate).

The two main groups of saline soils are not only diverse chemical nature of salts present, but also their physical, chemical and biological properties.

Reducing the amount and quality of humus in the soil

A manifestation of chemical degradation of soils may also be a reduction of the quantity and quality of humus in the soil and also reductions in the prompt and potential nutrients in the soil. Both forms of degradation (often called the plundering of land) relate mainly agricultural and arable land.

Humus is a dead organic matter present in the soil, regardless of their animal, plant or microbial origin. These substances do not remain in the soil unchanged subject for interaction of the soil microbial decomposition and various synthetic processes largely a biochemical basis, condensation polymerization, etc. Their composition, characteristics and quantity is constantly changing, the degree of conversion varies. After mixing with the mineral component of soil often create difficult organic-mineral and complex compounds. [184]

Quality of humus is distinguished according to various criteria, such as by degree of dispersivity, microscopic features, pH, source and botanical origin, etc.

The conversion process of dead organic matter to humic substances, called. **humification**, the biochemical nature and its course is conditional on the microbial activity of the soil with decomposition and synthesis process. [11]

Reduction of nutrients in the soil and soil solution

A manifestation of chemical degradation of soils may also be a reduction in the nutrient content in soil and soil solution. The nutrient content of the soil is an important part of arable land and affects the development of the soil, the chemical properties of soil and soil fertility.

Crop yields are crucially dependent on the abundance of these nutrients in the soil [184]:

- **macro-biogenic elements** - N, P, K, Mg, Ca, S, C, O, H,
- **micro-biogenic elements** - Fe, Mn, Cu, Zn, Mo, B.

Low, but also the members produces excess intake disorders in metabolism, reflected weaker growth, and various visual symptoms. [2]

Character of the individual soil types, depends on the composition of the mineral soil, the mode of existence of individual elements in the soil and the ability of the soil to stock up plant substances (nutrients) needed for their growth. [2]

The mineral part of the land consists mainly of the following elements [184]:

- **macro-elements** - Si, Al, Fe, Ti, Mn, Ca, Mg, K, Na, P, S, N,
- **micro-elements** - B, Co, Cu, Mo, Zn, Pb, Ni, Cr and others.

Chemical properties of the soil are also dependent on the characteristics of soil solution and soil particles. The water that seeps into the soil usually contains dissolved oxygen, CO_2, and a small amount of other elements. Soil has contacts the soil particles, reacts with them, enriched with various soluble substances; ion exchange allows the sorption complex of soil, etc. Under the influence of the CO_2 in the soil environment changes the pH of the solution thereby increasing the solubility of certain substances (Al). [11]

Soil contamination hazardous substances

Pollution (contamination) of soil affects agricultural production (fertility of crops, their nutritional value and hygienic quality), physical, chemical and biological properties of soil, filtering and buffering capacity of soil, composition and quality of surface and ground water, soil microorganisms life, etc. Together with the soil contamination, it is usually the starting point for the formation of residues in the food chain. For these reasons, the burden of agricultural soils foreign substances (contaminants) is undesirable practices. Hazardous elements are among the most important parameter for monitoring soil. [2]

Distinction is made between two main groups of contaminants [184]:

- **inorganic contaminants**, for example. heavy metals, metalloids (usually accumulate in the soil environment) only difficult to eliminate from the soil and the food chain,
- **organic contaminants**, for example. pesticides, polycyclic aromatic hydrocarbons, hydrocarbons, polychlorinated biphenyls, phthalates, and others.

8.4.3 Biological Soil Degradation

The biological activity of the soil is an important parameter assessment of production and ecological functions of soil. The large amounts of soil are living organisms, particularly bacteria, microscopic fungi, actinomycetes, algae, etc. (Tab. 40). [2]

The vast majority of living organisms in the soil has an indispensable role in the creation and reproduction of soil fertility. Soil organisms convert substances in the soil break down crop residues and help to convert them into humus and contribute to the exchange of material between the soil and other natural ingredients. [185]

Great importance is attached to soil worms, especially earthworms. They are an indicator of fertile soils. They are very sensitive to contaminants and agrochemicals. Increasing the number of earthworms (application of manure) in the soil contributes to an increase in biological activity and improving soil characteristics. [185]

A prerequisite for the preservation of critical biological processes in soil is favourable water and air regime of soil, adequate soil organic matter content, pH favourable soil and chemically undisturbed soil environment. [185]

The use of excessive quantities of fertilizers may reduce the ability of bacteria to decompose organic substances to other compounds that plants need for their life. Also, pesticides are harmful bacteria and other beneficial organisms in the soil. The land may also be contaminated e.g. industrial waste (e.g. heavy metals, air pollutants), and to receive in trace concentrations in the soil, which kill bacteria in the soil. [11]

At present, only three biological characteristics are generalized for the whole area of agricultural land in the SR: **carbon mineralization, nitrogen mineralization** and **nitrification in the soil.** [185]

Tab. 40

The occurrence of animals in the soil (an area of 1 m^2 with a thickness of 0,3 m)

Group	Quantity [cuts]
Bacteria	60 000 000 000 000
Mushrooms	1 000 000 000
Kelp	1 000 000
Single-celled plants	500 000 000
Worms	10 000 000
Mites	150 000
Eartworms	200
Snails	50
Spiders	50
Centipedes	150
Beetles	100
Fly larvae	200
Vertebrates	0,001

The mineralization of soil organic matter is measured by activity of microorganisms such the amount of released CO_2 from the soil. Agricultural land released annually into the air about

10 061 one thousand tons of CO_2 (one hectare of 3-5 tons). It is a value very close to CO_2 production industry (12 500 thousand tons per year). The natural process of releasing CO_2 from the soil shall not be considered environmentally undesirable. On the contrary, provides the necessary carbon cycle in nature. [185]

Mineralization of nitrogen in soil is the process of releasing mineral (inorganic) forms of nitrogen from soil organic matter. Annually agricultural soils released about 375 000 tons of mineral nitrogen. Average 1 ha of agricultural land each year creates about 162 kg of mineral nitrogen. It is an important principle of the formation of the productive potential of soils from their own resources. [185]

Information about the intensity of mineralization of nitrogen in soil are an important source of information for making fertilizer plans in Slovakia. At the same balance sheet is an important indicator for planning fertilizer consumption at the macroeconomic level. [185]

Nitrification is the biological oxidation of mineral nitrogen in the soil to nitrate. Approximately 110 000 t N - NO_3 are produced annually in agricultural soils of Slovakia. Average 1 ha of agricultural lands nitrified about 42 kg N - NO_3.

General principle that it is better soils of nitrate higher than lower quality soils. Nitrogen fertilization accelerates the formation of nitrate in the soil particularly in the improved soil.

8.5 Decontamination Polluted Soils

Maximum levels of pollutants (hazardous elements and a variety of harmful substances) are set by the relevant decree MoE SR. To avoid a possible transition to the food chain, they are therefore their content in soils continuously monitored and controlled. Unless contamination (contamination) there is carried out measures to ensure that the soil was again returned to its original state. These cleaning methods soils are referred to general concepts of **soil decontamination** [3].

Decontamination (clean) from the pollutants belongs to most complex ecological problems. With conventional small non-toxic pollution (within certain limits) ubiquitous soil bacterium can get over in soils. For example, it may relate to smaller oil spills. Usually it is sufficient for existing bacterial to strain to land suitable nutrients and the decontamination process further ensures nature itself.

For larger and larger across the board contamination (especially toxic substances) it is then necessary to use artificial decontamination process (technology). The choice of technology depends on the most favourable factors, the type and concentrations of contaminants, the type of soil, the depth of the soil and the like. Decontamination of polluted soils in terms of location technology can be transferred in two ways [116]:

- ***„IN SIT“*** - On-site contamination, without its workload,
- ***„EX SIT“*** - excavated contaminated soil venturing processing to another location. After cleaning, it may be rolled back or is used for other purposes.

Based on a deep and thorough evaluation of the nature of the contamination, the extent and location of the place, the next land use, economic possibilities and requirements for environmental protection must be chosen the most advantageous decontamination procedure.

For the decontamination of soils are most widespread following technologies [3]:

- **Thermal methods** - decontamination of soil thermal technology normally used to remove organic matter in large concentrations, as well as cyanide. Due to the high heat consumption, these technologies economically costly, technically challenging and require complex flue gas cleaning (as in hazardous waste incinerator).
- **Biological methods** - biological decontamination technologies are implemented primarily for oil products. Biodegradable oil hydrocarbons are removed in these technologies with special aerobic bacteria (Pseudomonas putida strain most often). The advantage of these technologies, it is possible to use both methods of implementation and to "*in situ*" and "*ex situ*".
- **Extract ways** - extracts of soil decontamination technologies can be carried out only as "*ex situ*", i.e. with stretched polluted soil (soil). Extract and flotation methods for decontamination are the most appropriate technology for removing heavy metals.
- **Solidification methods** - the essence of this technology lies in the fact that the physic-chemical treatment (addition of cement, lime, etc.) Or reducing its level of hazard. It reduces the rate for leaching contaminants, their mobility in soils. In some cases, the highly contaminated soil as input for the controlled dumping or the secured area. Before loading the dump often proceeded by solidification of extracted rock. These methods are used when the decontamination is technically and economically difficult to pursue. This typically involves contamination with heavy metals.

8.6 Soil Types and Grain Structures

Soil is a solid phase whose elementary particles (granules, grains) of different sizes (clay, gravel, colloids, stones, dust and sand) form a system of chemical and mineralogical composition. Particles of similar size form grain structures or fractions. The union of elementary parts with different cementing masses produces soil aggregates. Between aggregates are pores, **intra-aggregate** - found in the inner part of aggregates, **trans-aggregate** - passing through many aggregates and **inter-aggregate** - found between aggregates.

Porosity, as a soil property, is one of the most essential processes as it holds water in the soil, for rooting and for the cycling of solutions in the soil. [180]

Soil grain size as a soil texture, has the content of different fractions (clay, sand and dust) in the samples, which are given by weight percent. Soil types include colloidal dispersive textures that are less than 0,0001 mm in size, found in fractions of colloidal clay. They have a high active surface area, making them important factors in the high sorption properties of soils. (Clay is less than 0,002 mm in size, carries an electrical charge and has one of the largest specific surface areas. The distribution of the substrate by grain size is shown in Fig. 260.

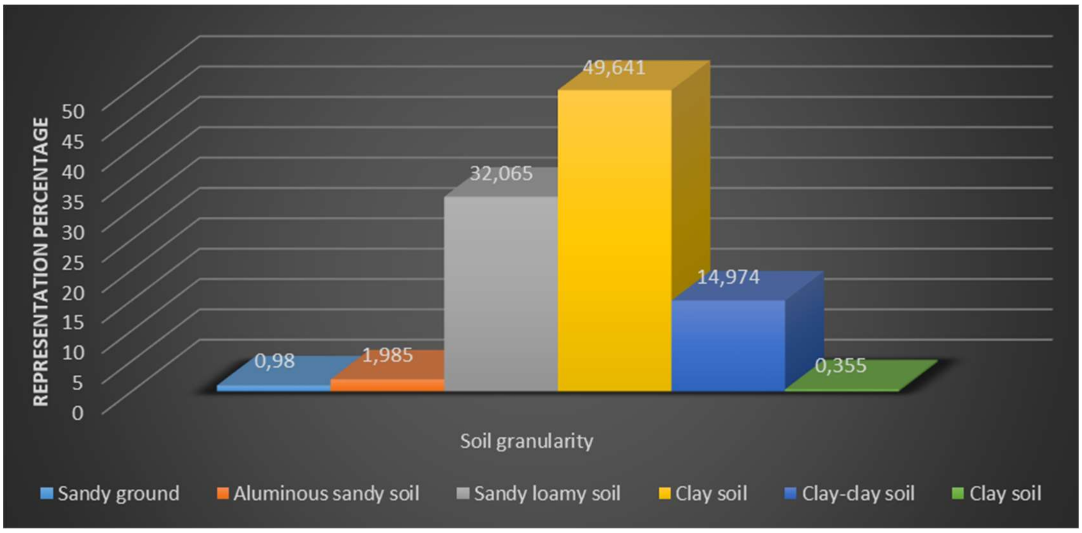
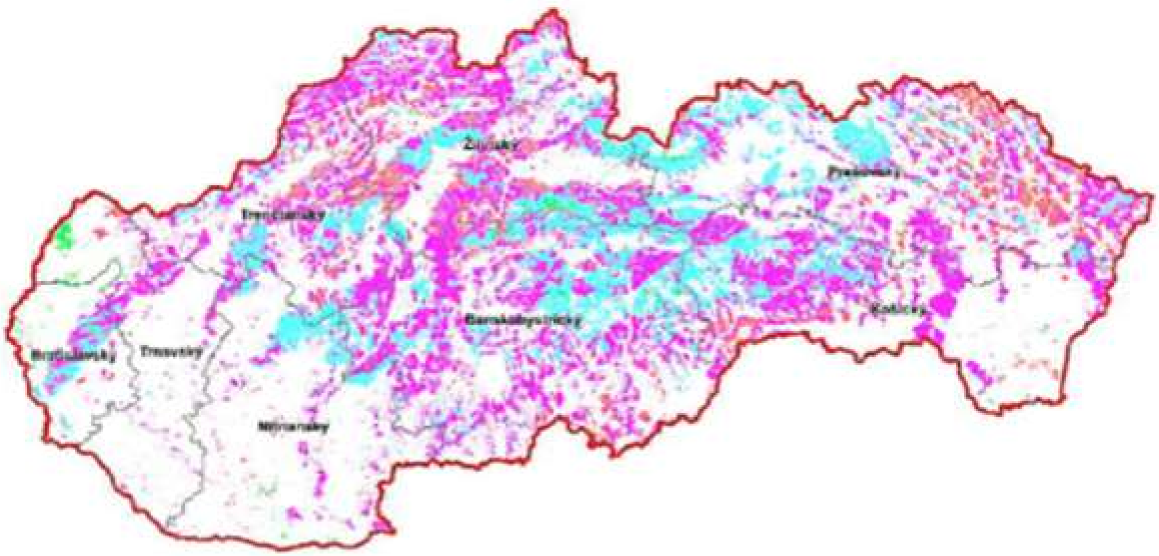


Fig. 260 Distribution of subsoil by grain size

Dust, dust particles ranging in size from 0,002 mm to 0,05 mm have a beneficial effect on both water and nutrient binding. Sand in the size range of 0,05 mm to 2 mm has the ability to attract less water. Skeleton (rubble) consists of rock and mineral fragments larger than 2 mm. The percentage distribution of soils in Slovakia is shown in Fig. 261. Distribution of soils in Slovakia according to grain size composition. [182]



Legend:

- SR border
- The border of the region

Soil granularity:

- Sandy ground
- Aluminous sandy soil
- Sandy loamy soil
- Clay soil
- Clay-clay soil
- Clay soil

Fig. 261 Map of the distribution of soils in Slovakia by grain size composition

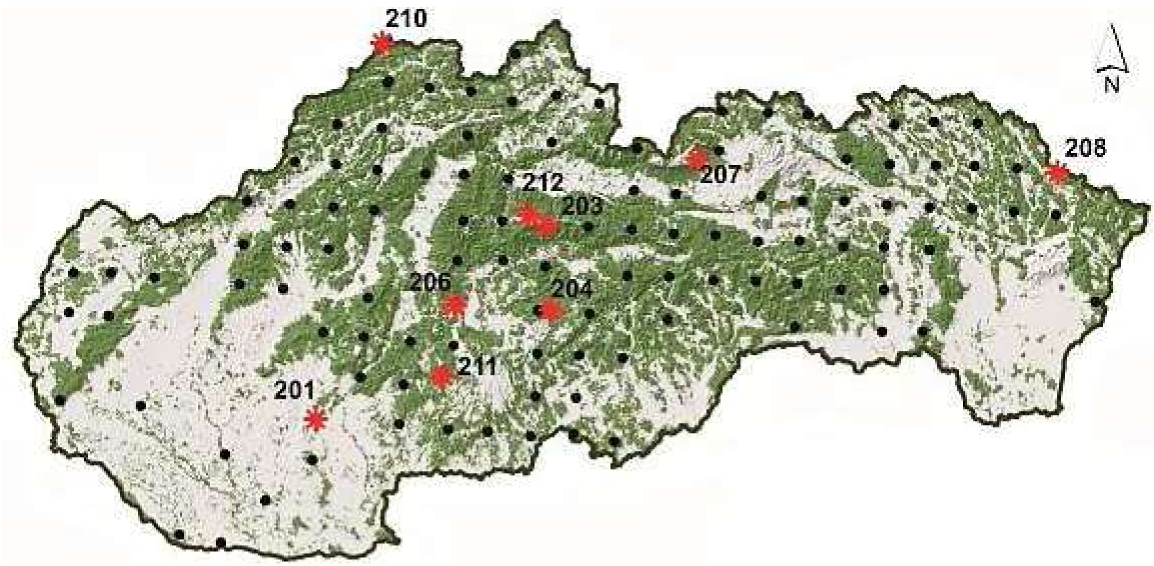
8.6.1 Most Common Sources of Contamination

If we evaluate the origin of contamination of geological parts of the environment, we come to the problems associated with sites that are contaminated with a multi-sectoral character, even if the soil whose sections according to the impact on the environment have a lower or higher priority. It is necessary to consider the impacts in terms of environmental contamination, also by addressing the problem in the contaminated areas [2]:

- burning of fossil fuels,
- agriculture (cooperatives, farms),
- petrol stations, refineries and product pipelines,
- military bases,
- mining activities,
- metal metallurgy,
- waste management,
- construction, chemical industry and engineering.

The densest network in Slovakia is the area survey of contaminated soils, the location and density of monitoring areas. It includes approximately 15 433 sites and their distribution is geometrically irregular. As an example, the forest monitoring system has two basic levels (Fig. 262) [11]:

- extensive large-scale monitoring,
- monitoring that is intensive.



Legend:

- Extensive monitoring - level I.
- Intensive monitoring - level II.
- Forest area

Fig. 262 Forest monitoring network

8.6.2 Description of Sampling Areas

Poráč is the only mining tower, functional and active underground mine in the Spiš area, where currently only barite is mined. The eastern Rudňany veins were initially mined mainly for various silver and copper ores. Later, limonite was mined, forming a massive gossan, in the upper Droždiak area near Poráč. A huge opencast mine was created after its extraction. Mercury was also mined in the mid-19-th century from cinabarit and tetrahedrite. Siderite mining was also added. [186]

The mining development was also largely related to the construction and building activities of the railways between Košice and Bohumín. A new iron ore roasting and processing plant and, after a long period of time, a mercury plant were also built. In the 1970s, the Poráč mine was built. The depth of this shaft was about 504 m and consisted of seven floors, the horizons. The mine has been self-closing for some time, so it is not possible to mine all the horizons. Nowadays it is mined to a depth of 283 m, i.e. to the fourth floor, which is called Rochus.

The Poráč shaft is also more or less connected to the nearby ore processing plant in nearby Markušovce. In 1993, five shafts were in operation with a depth of 504 m - Poráč pit, 5 RP - 2 678 m, West - 724 m, Peace - 485 m and Zlatník pit - 723 m. [186]

8.6.3 Sampling

The following parts and procedures were carried out in the experiment [186]:

- analysis of possible sources of contamination of soils in the Eastern Slovakia region, taking into account the areas of the Rudnany - Gelnicka mining district,
- analysis of the possibility of collection and processing of plant and soil samples,
- analysis of individual methods of isolation of elemental forms from these samples,
- experimental part of mobility of elemental forms in the selected area,
- conducted research on possible bio-sensors and (further) use of selected plants for potential monitoring of contamination of the area over time.

One of the most specialized types for routinely sampling undisturbed grassland or agricultural soils are most commonly profile samplers (Fig. 263), which retain the root system of the vegetation when sampled. The depth of the sampled profile, usually 40 cm, limits the height of the sampler. When comparing profiles taken with a core sampler and a profile sampler, it can be clearly seen that a sample taken with a profile sampler shows much less compression. This makes it easier to describe the soil structure. [186]

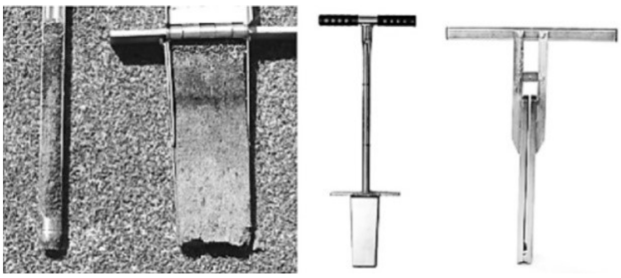


Fig. 263 Examples of core samplers for grassland sampling [186]

Two soil samples and two moss samples were collected for experimental transport. Soil samples were taken first at the Rochus mine and second at the processing plant (Fig. 264), with almost no vegetation present in some sections (Fig. 265). Mosses were sampled near the plant. The collection of individual soil and vegetation samples was generally aligned with the requirements and sampling steps. The monitoring site on the special agricultural soils is circular in shape (area approx. 315 m^2) with a radius of Ø 10 m. [186]

Fig. **264** Shaft [186]

Fig. 265 View of processing plant 2 [186]

Individual soil and plant samples were collected on 3 October 2014, the time of collection was 12:00 at 7 °C. A spade was used to expose the top of the soil profile in a perpendicular direction to a maximum depth and length of 30 cm (Fig. 266). A 5 kg soil sample was collected in a labelled bag. [186]

Fig. 266 Soil sampling [186]

Plant samples were used for additional heavy metal analysis with interpretation into soils. They were collected from the central area of the monitoring plot. The moss types found with the mosses near the plant were: grey moss (Leucobryumglaucum) (Fig. 267) and common plonk (polytrichumcomunne) (Fig. 268). [186]

Fig. 267 White-eyed Susan [186]

Fig. 268 Plonium common [186]

The treatment of the soil samples consists of three points [186]:

1. **Pre-treatment** - accelerated drying of admixtures is observed. The soil samples are transferred from plastic bags into flat containers or onto larger paper, broken into smaller pieces with the fingers and mixed and dried at different time intervals. During drying, coarse organic impurities (roots, leaves and other plant organs) as well as other impurities (glass fragments, stones, skeleton) must be eliminated from the samples.
2. **Fine grain recovery** - elementary particles smaller than 2 mm that are thoroughly stripped of fine organic and contaminant impurities (roots, plant organ fragments, etc.). Preparation of fine soil from a 200 ml batch, is poured into a larger pad of approximately 500 x 500 ml, made of hard, thick rubber (5 mm) or PVC flooring. The clumps and aggregates are then slowly spread with a wooden roller so as not to destroy the skeleton particles and fine earth. Gravel, thin roots, finer foreign matter and new growth are removed. After the larger parts of the tailings have been spread and the unnecessary impurities removed, the soil is sieved and screened with a 2 mm diameter sieve. The smaller soil particles remaining on the site are again sieved and screened after thorough removal of the coarser parts until only the skeleton remains. The sample is then spread on clean smooth paper in a thin layer (maximum 3 mm) and the paper is shaken in a horizontal direction, this step brings the dirt to the surface.

After these procedures, the fine earth is prepared and taken directly to the laboratory for more detailed analysis.

3. **The actual procedure** - a loose sample, or fine earth, is poured out on smooth clean paper, which is aligned in a layer a few millimetres thick and divided into approximately four equal parts with two lines. The samples are divided in this way until the quantity necessary for weighing remains. For special analyses, the finer sieves are passed through finer sieves with a sieving diameter of 0,13 mm.

The soil samples are prepared in Fig. 269 and Fig. 270.

Fig. 269 Soil sampled [186]

Fig. 270 Soil quartication [186]

The sieving of the moss and soil samples occurred on 9 October 2014 in the drying room. The samples were sieved with a sieve thickness of 2 mm (Fig. 271 and Fig. 272) free of the already unwanted parts that did not pass through the sieve. The fine soil was prepared, approximately 200 ml of sample was taken and sieved onto a pad which was made of hard rubber. The individual clumps were rubbed (Fig. 273) and the smaller stones and small unnecessary impurities were removed and the sample was sieved through the sieve again. The finer impurities were removed with tweezers. [186]

Fig. 271 Crushed bryophytes - mosses [186]

Fig. 272 Examples of sieves [186]

Fig. 273 Clumps of soil samples and contaminant particles

Fig. 274 Fine soil [186]

8.6.4 Determination of Heavy Metals in 2 M HN03 Leachate

At the beginning of the experiment, the equipment, apparatus and also the extraction reagent (2M HNO_3) were prepared and were an integral part of the experiment (Fig. 275). Subsequently, the laboratory equipment was washed with 4M HNO_3 and rinsed with distilled water. [186]

Fig. 275 Experiment preparation [186]

The 5 g of soil and plant sample were weighed into 250 ml resealable containers (Fig. 277). Subsequently, 50 ml of bimolar nitric acid was added. Subsequently, 0,05 M EDTA was measured on an F-AAS atomic absorption spectrometer (Fig. 276). [186]

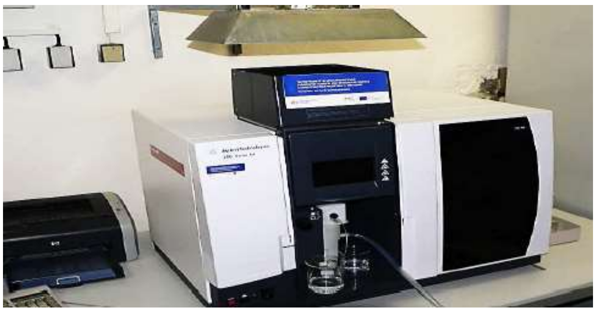


Fig. 276 F-AAS atomic absorption spectrometer

Fig. 277 Shaker [186]

On a horizontal shaker 0,05M EDTA was extracted for one hour at 240 rpm and cold, When the shaking period was completed, the given contents were poured into the extraction vessels and the soil suspension was filtered through filter paper into a 100 ml dry plastic container The first 4 to 11 ml of substrate was removed. [186]

The results of the individual heavy metal measurements from the soil samples are shown in Tab. 41 and Tab. 42, which shows that the Rudňany area is the most contaminated with mercury, especially in the vicinity of Poráč, as a result of long-term mining activities. The measurements also revealed elevated amounts of arsenic resulting from the individual geochemical influences of the Spiš-Gemer ore zones. [186]

Tab. 41

Comparison of 0,05M EDTA and 2M $HN0_3$ [186]

Sample number	Sample	0,05M ESTA	2M HNO_3
		RSD [%]	RSD [%]
1.	Cd	10,62	12,94
2.	Pb	24,15	26,62
3.	Zn	39,20	39,91
4.	Cu	26,63	29,01
5.	As	35,61	37,99
6.	Hg	38,64	40,71

Tab. 42

Results from measurements of heavy metals in environmental samples [186]

Sample number	Cd		Pb		Zn		Cu		As		Hg	
	0,05M EDTA	2M HNO_3	0,05M EDTA	2M HNO_3	0,05M EDTA	2M HNO_3	0,05M EDTA	2M HNO_3	0,05M EDTA	2M HNO_3	0,05M EDTA	2M HNO_3
1.	10,60	12,90	24,10	26,60	39,16	39,90	26,59	28,98	35,60	37,98	38,62	40,70
2.	8,20	8,70	29,15	31,50	38,58	38,85	25,10	27,07	31,16	31,42	37,31	38,20

The second part of the experiment from the contaminated area is devoted to the investigation of heavy metals mobility in phytomass and in the specific area of Rudniansky district. The mobility of elemental forms of heavy metals in mosses growing in this area was investigated. [186]

The species Leucobryumglaucum - Grey moss and Polytrichumcommune - Plonium vulgaris were selected as representative moss samples. Of these selected mosses, samples of grey white moss showed better ability to attach to their cellular parts, having on average 3 times greater bioaccessibility of heavy metals than the moss forms of common plonk moss, Tab. 43. These findings can be attributed to the soil type and mineralization composition under the site, which create better conditions for the life of this moss species in the area. It is possible to draw conclusions, that for (further monitoring and control of the contamination of the area as a bio-sensor, white moss can be used for monitoring the area of contamination in terms of time. [186]

Tab. 43

Heavy metals in selected mosses [186]

Moss	Cd	Pb	Zn	Cu	As	Hg
	2M HNO_3					
White-eyed Susan	5	7,5	13	10,1	12,7	13,2
Plonium common	1,2	1,9	3,6	3,1	3,4	3,7

9 ENGINEERING PRODUCTION AND ENVIRONMENT

In the next part of this chapter, the authors focused on presenting the results of their scientific research work aimed at determining the optimal volume of production taking into account environmental criteria, as well as a possible environmental assessment of engineering products in their conceptual phase [5, 8, 187].

9.1 Determining the Optimal Volume of Production Taking into Account Environmental Criteria

Determination of the optimal production volume, applying mathematical methods and eco-design principles is a significant step towards the presentation of environmental and economic problems at source and hence towards a more sustainable society. Integration of environment aspects into the familiar product development process is important from both the environmental and business perspective. Eco-design projects, including exact methods, carried out all over the world have shown that besides helping improve the environment, eco-design and its mathematical tools also often offer business financial benefits [187, 188].

Exact access of the developing engineering products is one of the possibilities, how to achieve the environmental and economic objectives. There are a lot of different analytical tools, by means of it can be carried out. One of such tools is described in this paper.

9.1.1 Environmental and Economic Factors and Their Expression

Preferably let us consider a production complex (for example, an engineering factory), situated in some locality, manufacturing x products during a time unit. The different harm-full components are created in that process, too, having impact on the environment. The disposable quantity of the so-called natural capital is necessary to the activity of the considered production system. Natural capital is classifying to the non-renewable natural resources and is derived from the environment. Minerals and fossil fuels are included in this category [189, 190, 191]. The structure of natural capital can be the following:

- ores and their concentrates,
- raw material of energetic character (except of natural gas and - crude oil,
- natural gas,
- crude oil.

Some sources and authors include selected metals and their semi-finished products, selected plastics and their semi-finished products, consumption of electric energy per year. [189, 192, 193, 194]

Let C_1 is a disposable quantity of natural capital during a year, for production of x products [196, 197].If the value of x is increasing; of course, the value of C_1 will be decreasing. The following formulas can express this situation - $C_1/_x \rightarrow 0$, and

$$K_1(x) = \frac{C_1}{x} \tag{9.1}$$

The factory must carry out activities for environment protection according to the valid legislature. Starting from the environment protection structure [187, 197, 198, 199] these costs can be expressed as

$$NOZP = EK + ENV + SOC \tag{9.2}$$

where:

NOZP - total costs for environmental protection,
EK, ENV, SOC - main cost components of economic, environmental, and social character.

The economic part consists of these particular ones:

$$EK = INV + PREV + SAN \tag{9.3}$$

where:

INV - capital expenditure in connection to the environment protection,
PREV - over-heads of the factory,
SAN - costs depending from the environment degradation (fines, fees, etc.).

The over-heads depend from the quantity of manufactured products *x*, so

$$PREV = V * x \tag{9.4}$$

where:

V - manufacturing costs per one unit of product.

Environmental part of the total costs consists of two items:

$$ENV = VONK + VNUT \tag{9.5}$$

where:

VONK and *VNUT* - are environmental costs from the point of view of so called outside and inside environment, if

$$VONK = (ODP + EMO + EMV) * x \tag{9.6}$$

and

$$VNUT = IM * x \tag{9.7}$$

where:

ODP - quantity of solid wastes,
EMO - quantity of emissions,
EMV - quantity of liquid wastes,
IM - quantity of imissions inside the factory

All the presented items are incipient during the manufacturing of one product.

Particular result for the ENV is:

$$ENV = (OPD + EMO + EMV + IM) * x \tag{9.8}$$

If the total costs for environment protection will be signified as K2(x), then after some derivations,

$$K_2(x) = C_2 * x + INV + SAN \tag{9.9}$$

where:

$$C_2 = V + ODP + EMO + EMV + IM \tag{9.10}$$

The total costs for the manufacturing of x products in a factory, can be expressed as $K_{(x)}$ = $K1_{(x)}$ + $K2_{(x)}$, and applying the substitutions, the following equation is obtained:

$$K(x) = \frac{C_1}{x} + C_2 * x + INV + SAN \tag{9.11}$$

The optimal number of products x is can be obtained after the differentiation of the equation (9.11) - i.e.

$$\frac{dK(x)}{dx} = -\frac{C_1}{x^2} + C_2 = 0 \tag{9.12}$$

and

$$x_{opt} = \sqrt{\frac{C_1}{C_2}} \tag{9.13}$$

If *x* = x_{opt} and *INV + SAN = C3*, after substituting these expressions to the equation (11), the minimal value of the function $K_{(x)}$ is determined as

$$K_{\min} = \frac{C_1}{\sqrt{\frac{C_1}{C_2}}} + C_2 \sqrt{\frac{C_1}{C_2}} + C_3 \tag{9.14}$$

The graphical interpretation of these results is given in Fig. 278.

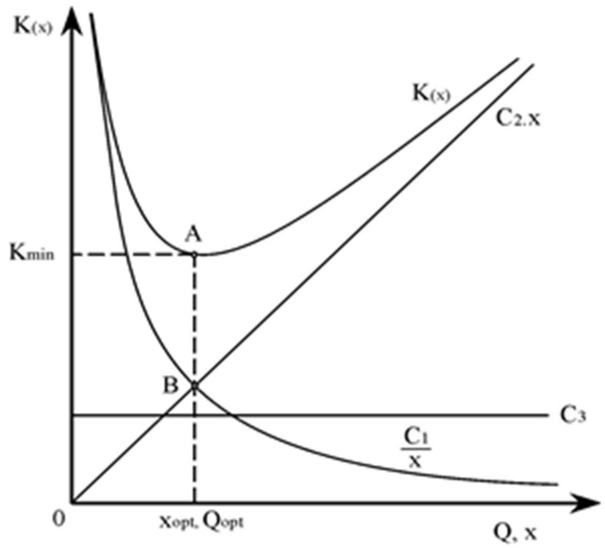


Fig. 278 Graphical interpretation of the compromise solution between the economic and the environmental demands in the mechanical engineering industry

The discussion deals with:

- The curve $K_{(x)}$ sometime called as the curve of the sustainable development - has its minimum (point A), and represents, according to some approach, the compromise solution between the economic and the environmental demands on the micro-economic level.
- Consumption of the natural capital (habitually per annum) is gradually reduced by growing production, which is compensated with costs - to eliminate this consumption. Point B represents equality of both - costs and thus the economic optimum of the environment quality - Q_{opt}.
- The environment protection costs have their initiation part of the constant value, which consists of the capital expenditure part INV and constant payments SAN. It is presumed that SAN = const., to the $x = x_{opt}$ value. If $x > x_{opt}$, it will probably depend from the other concrete conditions.
- Perhaps, the presented method and approach can be applied to some parts in the LCC (Life Cycle Costing) analysis.

9.1.2 An Application in the Automotive Industry

An European redoubtable car producer has provided some important input data to test the method described in this paper. These data are intentionally misrepresented (because of the firm secret). According to the provided data, the particular values of the function $K_{(x)} = f_{(x)}$ have been computed for a passenger car - vehicle weight ~ 1200 kg, and the following material structure [in %]: Ferrous 66, Aluminum and other light alloys 12, Plastics 12, Rubber 4, Glass 4, Zinc 1,5, Copper and its alloys 0,5 [193, 199]. The computed data are illustrated in Tab. 44.

The graphical representation of the function K(x), and its relevant parts, is illustrated in Fig. 279.

Tab. 44

The particular values of the function $K_{(x)} = f_{(x)}$, the numbers in the right side of the columns are the exponents y, the particular values in the left side of the columns are multiplied by 10y

x	y	C_1/x	y	$C_2.x$	y	$K_{(x)}$	y
1		5,00	11	8,50	9	5,08	
2		2,50	11	1,70	10	2,67	
3		1,66	11	2,55	10	1,92	
4		1,25	11	3,40	10	1,59	
5		1,00	11	4,25	10	1,42	
6		8,33	10	5,10	10	1,34	
7	5	7,14	10	5,95	10	1,31	11
8		6,25	10	6,80	10	1,30	
9		5,55	10	7,65	10	1,32	
10		5,00	10	8,50	10	1,35	
11		4,54	10	9,35	10	1,38	
12		4,16	10	1,02	11	1,43	
13		3,84	10	1,10	11	1,48	
14		3,57	10	1,19	11	1,54	
15		3,33	10	1,27	11	1,60	
16		3,12	10	1,36	11	1,67	

The C_3 part is not illustrated in Fig. 279, because of its irrelevant influence and constant value. Some comments to the Fig. 279:

- Value K_{min} of the curve $K_{(x)}$ expresses a compromise between the economic and the environmental demands.
- The curve C_1/x is the curve of the natural capital consumption during the car production in the factory.

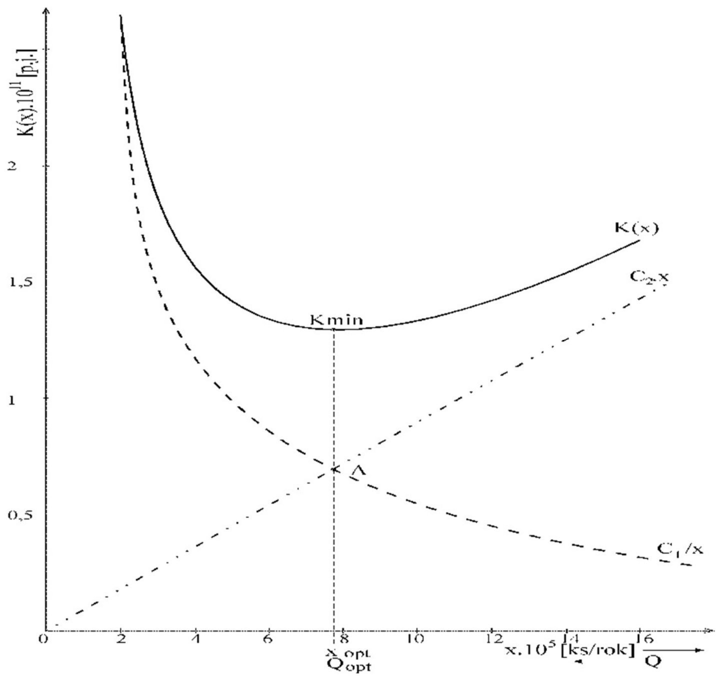


Fig. 279 The curve of the sustainable development for the presented application (the passenger car production) [191]. Abbreviations: m.u. - monetary unit pc - pieces

- x_{opt} is the optimal car production volume per year (about 7.8.10^5) for the given conditions.
- Q_{opt} is the optimum value of the environment quality for the given production process character.
- Point A represents the compromise solution.

There is the need for systematic approach to organize a factory in such a way that improving the environmental and economic performance of their products across product life cycles becomes an integrated part of operations and strategy. Determination of optimal production volume has operational and strategic purpose, too. The described method represents the way, how to determine it. An application in the automotive industry, this approach can bring not only environmental, but also economic benefits, as shown in the paper.

9.2 Environmental Evaluation of Mechanical Engineering Products in their Conceptual Phase

Improving product design by applying ecodesign principles is a big step towards the presentation of environmental problems at source and, hence, towards a more sustainable society. Ecodesign, or the integration of environmental aspects into the familiar product development process, is important from both the environmental and business perspective [57, 188, 190, 204]. Ecodesign projects carried out all over the world have shown that as well as helping improve the environment, ecodesign also often offers business financial benefits [206, 207, 211].

Environmental assessment of the developing engineering products, one of the possibilities, how to achieve the environmental and economic objectives. There are a lot of different analytical tools, by means of it can be carried out [205, 212].

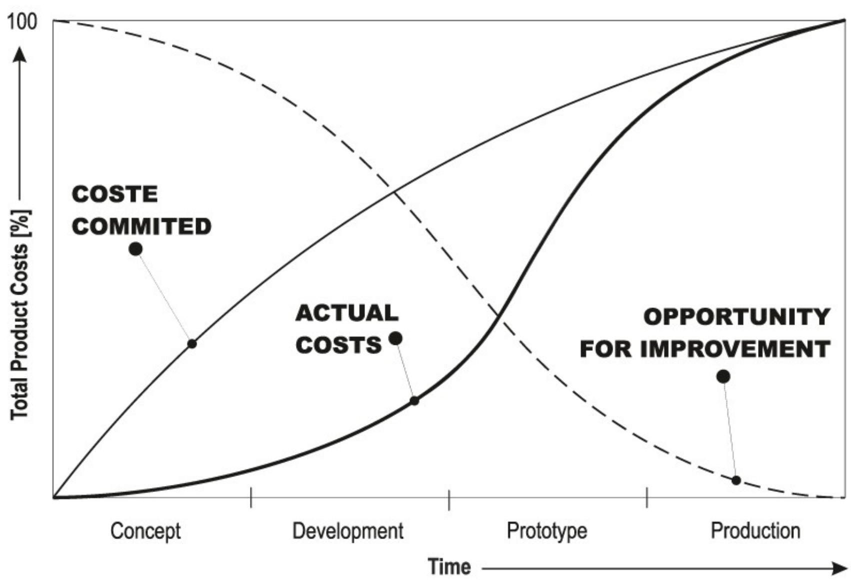


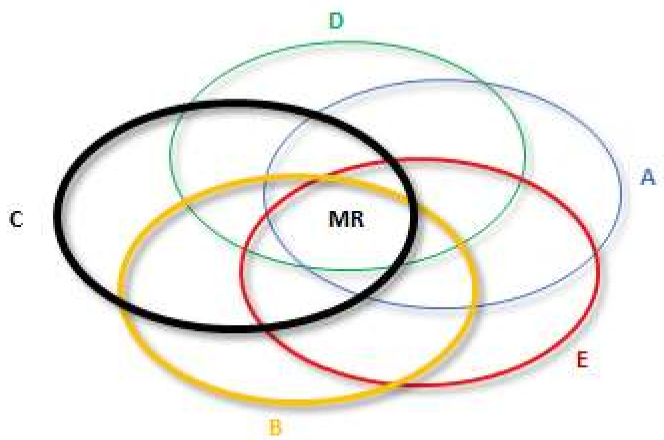
Fig. 280 The product development process [209]

The product development process is often regarded as a systematic process, and several methods are described in the literature. However, reality presents several unexpected events, and substantial changes in plans are common. In the beginning, the degree of freedom decreases and the cost for changes increases. These ideas are taken into consideration by some authors, for example, Steen [210], Sutherland [209], and some others. A similar approach has been applied in the EcoCAD System [208]. The Sutherland's diagram - Fig. 280, very well catch the described considerations given above.

One of those tools, based on Software, focused on the conceptual phase, is described in the following parts of this paper.

9.2.1 D/D Procedure of MEP-s and its Formal Expression

At the present time, an up-to-date MEP-s must fulfil the technical, economic, environmental, and aesthetic market requircmcnts. Fonnal expression of these requirements is carried out by means of a set system. Its graphical representation is in Fig. 281.



Abbreviations: A - technical, C - economic, D - environmental, B - aesthetic,
E - market requirements,MR - area of the possible solutions

Fig. 281 Graphical representation of the different requirements on the up-to-date MEP-s using the set system

Put simply, with conventional D/D constraints a solution had to be found in the MR area, where the four basic spheres overlapped. The addition of the EN sphere has modified the scope of possible solutions which must be chosen from within the area where all spheres overlap. By this way environment has been integrated into MEP-s D/D.

It is well-known, that eco-design means integrating environmental aspects into product design and development.

The formal expression of these relations is the following:

$$A \cap B,\ A \cap C,\ A \cap D,\ A \cap E,$$
$$B \cap C,\ B \cap D,\ B \cap E,$$
$$C \cap D,\ C \cap E,$$

$$D \cap E$$
$$MR \subset A,\ MR \subset B,\ MR \subset C,\ MR \subset D,\ MR \subset E.$$

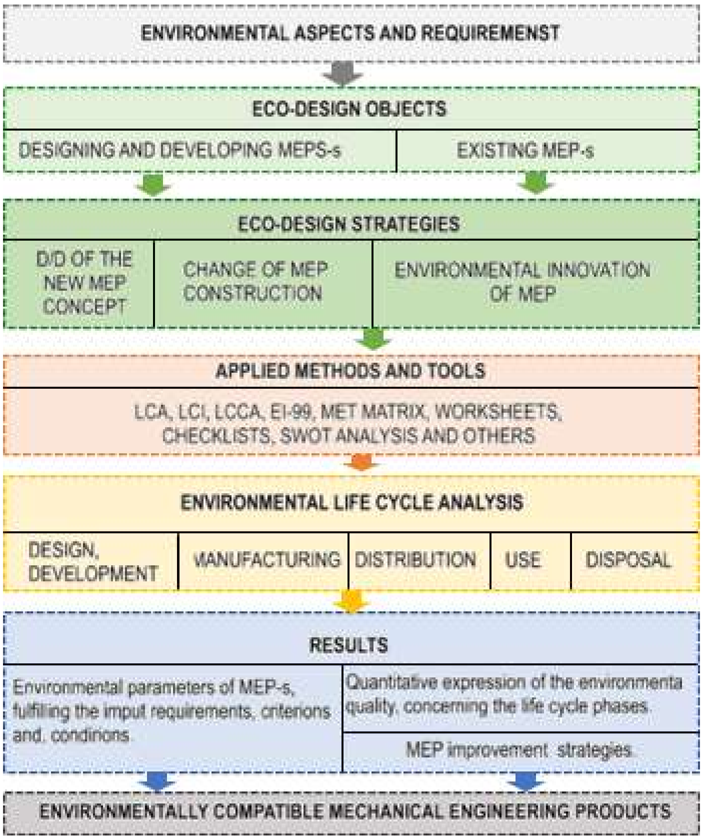
For an optional element x, from the subset MR, it can be written:

$$x \in A,\ x \in B,\ x \in C,\ x \in D,\ x \in E,$$
$$and\ \{x_1, x_2, \ldots, x_i, \ldots, x_n\} \in MR.$$

From the practical point of view it means, that an optional x represents a suitable solution, which fulfils all requirements, given by the sets A, B, C, D and E.

9.2.2 Eco-Design Philosophy for MEP-s

Reference document on eco-design is the standard XP ISO/TR 14062 (2002) and its derivative for the Slovak conditions - Act NR SR No. 665/2007Z.z. Starting from these standards, a eco-design philosophy for MEP-s has been obtained. Its graphical expression is illustrated in Fig. 282.



Abbreviations: LCA - Life Cycle Assessment, LCI - Life Cycle Inventory, LCCA - Life Cycle Cost Analysis, MET - Materials, Energy, Toxicity, SWOT - Strengths, Weaknesses, Opportunities, Threats, D/D -Design and Development.

Fig. 282 Scheme of eco-design philosophy for MEP-s

9.2.3 Conceptual Phase of Eco-Design - The Most Important part of the MEP-s Life Cycle

Almost all properties of the D/D MEP-s are determined in their conceptual phase. The D/D of an environmentally friendly MEP requires the assessment of its potential environmental impact during the D/D process. Particularly in the early MEPD/D stages, the potential for environmental optimization is high Fig. 283.

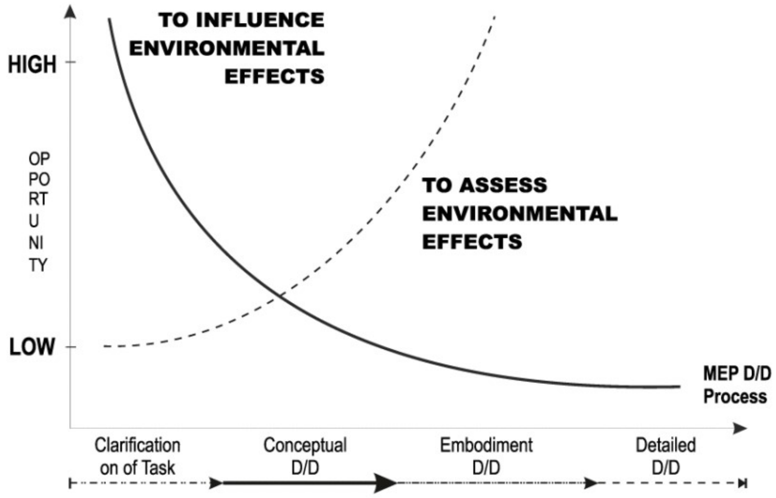
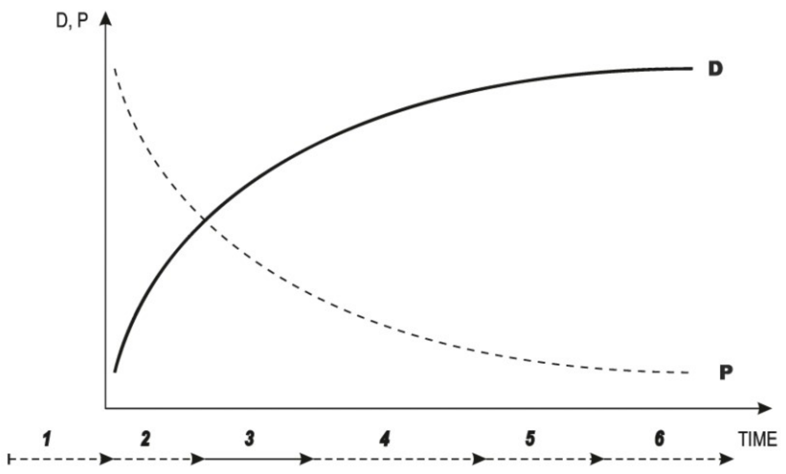


Fig. 283 Opportunities to influence and assess environmental effects during the MEP-s D/D process

Once the requirement has been defined in the requirements list, the MEP designer and developer has to convert them into concepts. An MEP concept is an approximate description of systematically generated and assessed principle solutions. In the course of the concept D/D process, the solutions are generated by a stepwise concretization of the MEP-s functions, physical effects and working principles and assessed with regard to the requirements defined in the requirements list. In the following, the concepts serve as the basis for the embodiment and detailed D/D Fig. 284.

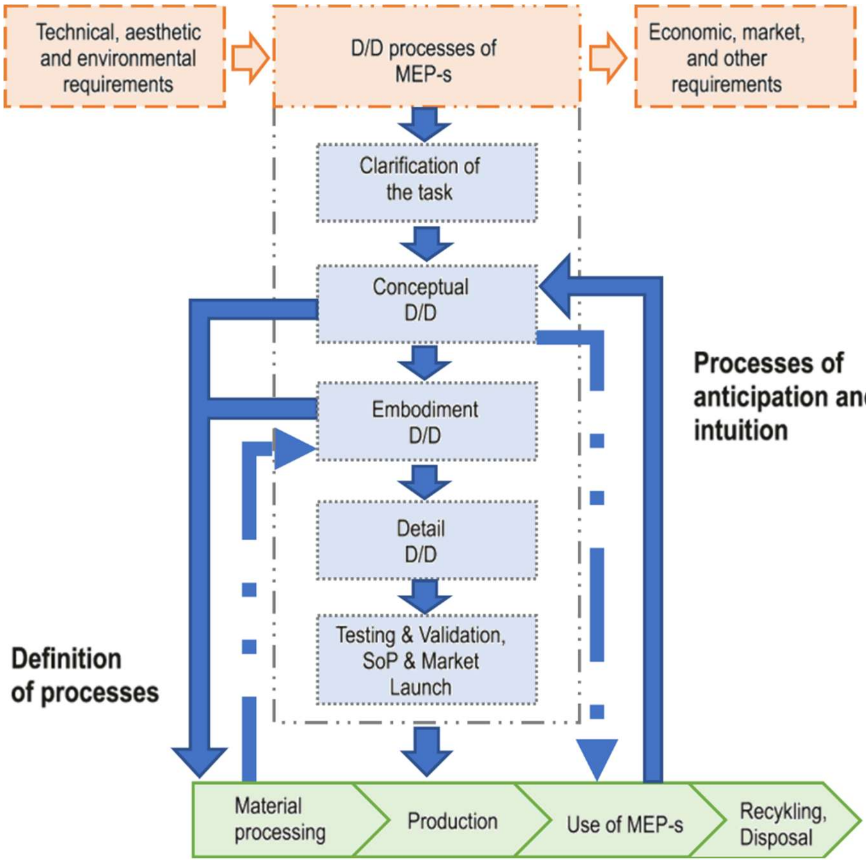


Abbreviations: D - Definition of Costs, Quality, Eco- Effectiveness, P - Possibility to influence the D/D, 1 - Potential & Risk Identification, 2 - MEP Definition, 3 - Conceptual D/D, 4 - Embodiment & Detailed Design, 5 - Testing & Validation, 6 - Start of Production and Market Launch

Fig. 284 Relations of the conceptual D/D phase of MEP-s to the other life-cycle phases

This approach, described in [200], has been applied as one of the basic principles in the CoDe-09 software product.

The concept of Integrated Product and Process Development (IPPD) is illustrated according to its scheme in Fig. 285.



Abbreviation: SoP - Start of Production

Fig. 285 Concept of the Integrated Product and Process Development of MEP-s

9.2.4 The CoDe-09 Software and Applied Methods

The aim of the development of the CoDe-09 software has been that a developer, who is a user of this system, is able to obtain the required results in connection to the assessed conceptual variants of MEP-s.

Some conceptual variants of an MEP are represented by their functional or working principles. The question has been: Which of them is best from the environmental point of view? It is well-known, that in the conceptual phase of D/D there are no suitable technical, economic or other data to compare the variants available. If the approximate results are sufficient (for the first orientation), **Guideline VDI 2225** and its analogy can be applied [188]. The different concepts can be accessed on the basis of environmental criteria with values expressed by points ranging from 0 (unsatisfactory) to 4 (ideal). The pre-requirement for the application of this method is the functional decomposition of a design unit, representing its own functional or working principles, to the simplest functionally conjoined parts (FCP-s). The

FCP-s need to be understood as a **non- reducible complex system,** taking away only one part - the system becomes defunct (see the theory of systems).

If more exact results are required, it is necessary to apply some other approach and methods. The EI-99 method [191] has been applied in this case, in the CoDe-09 software. Of course, to apply it, a lot of specific data must be at one's disposal (amount and type of materials, energy consumption, consumption of consumables, manufacturing procedures, etc.). In this case, the simplest functional part is a component.

9.2.4.1. Structure of the CoDE-09 System

The architecture of the CoDe-09 system is [191] of building-block form and has hierarchical relations between the program modules (Fig. 286).

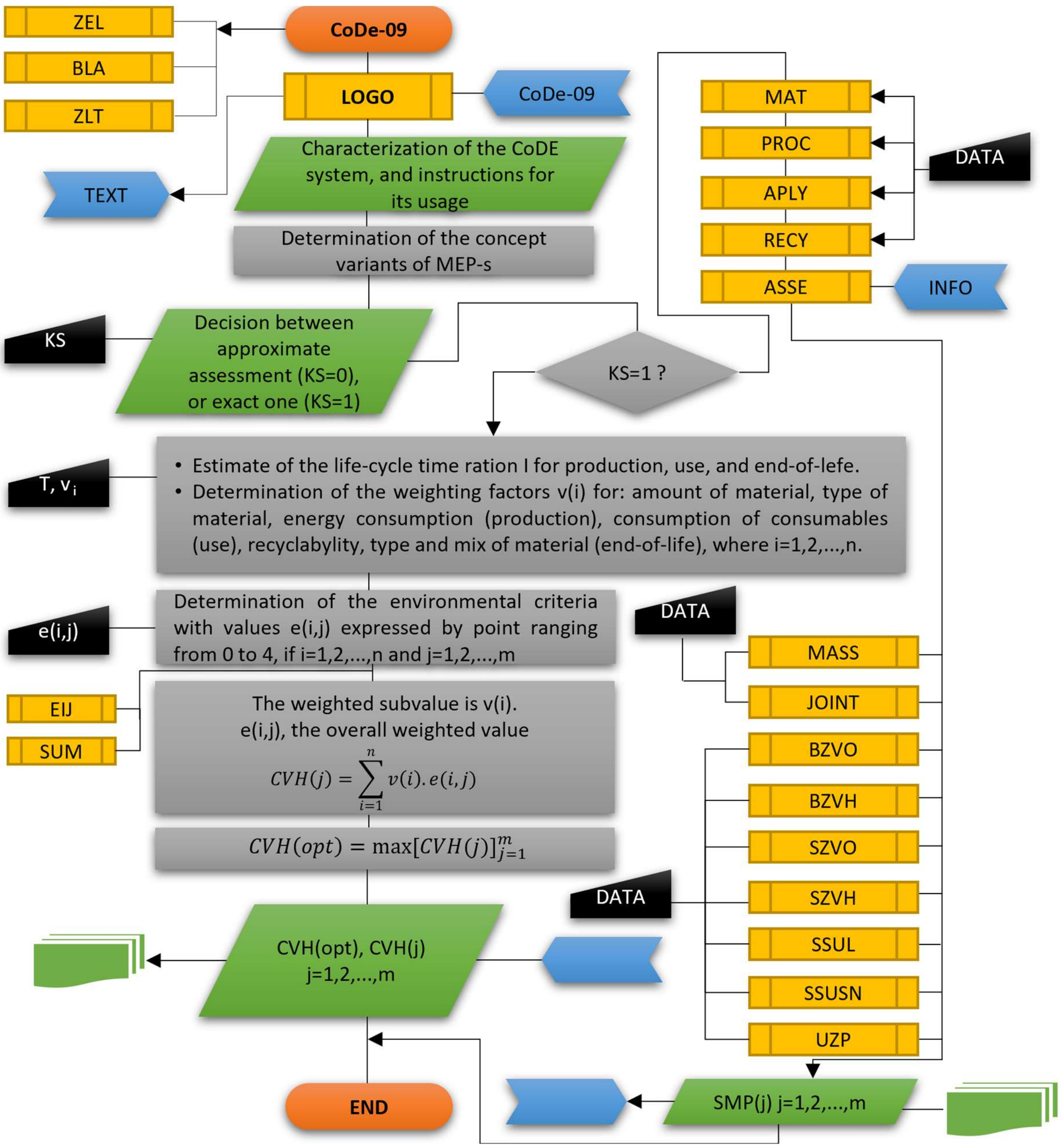


Fig. 286 Software configuration of the CoDe-09 software

At present, there is an informational part (system characterization, and instructions for its us age), determination of the basic input data (data concerning the different concept variants|, and of course, generation of the promotional spot (modules LOGO, etc.).

After it, processing is divided in to two flows - approximate environmental assessment of concept variants, and the exact one. In the first case, there are 4 master programmes and 2 sub-routines (EIJ and SUM). In the second one, there are 5 master programmes (MAT, PROC, APLY, RECY, ASSE) and 9 sub-routines (MASS, JOINT, BZVO, BZVH, SZVO, SZVH, SSUL, SSUSN, UZP).

Output data is: CVH - overall weighted value, SMP(j) - overall sum of mP (milipoints), j= 1,2,...,m, j - variant index, m - no. of variants, i=1,2,...,n, i-parameters index, n - no. of parameters. Other information is evident from the flow-chart in Fig. 286.

9.2.5 An Application in the Automotive Industry

The presented application is in connection to the three concepts of a passenger car door frame, and their environmental assessment.

The basic input data:

1. **Variant -** The car door frame consists of 5 components (Fig. 287), applied material is steel, and spot welding is applied during assembly.
2. **Variant -** like in the 1. variant, of course, the applied material is aluminium.
3. **Variant -** The car door frame is a composite construction and consists of one component only. Applied material is PA + mineral fibres - reinforced (armed).

Approximate assessment:

- j-variant index, no. of variants m = 3,
- i-item index, no. of items n = 6,
- Input data:

$$T_v = 0{,}3,\ T_p = 0{,}6,$$
$$T_d = 0{,}1\ (T = T_V + T_P + T_d = 1!);$$
$$v_1 = 0{,}13,\ v_2 = 0{,}13,\ v_3 = 0{,}32,\ v_4 = 0{,}32,$$
$$v_5 = 0{,}1,\ v_6 = 0$$
$$(v_1 + v_2 + v_3 + v_4 + v_5 + v_6 = 1!);$$

***j* = 1**

$$e_{11} = 3\ ,\ e_{21} = 3,\ e_{31} = 2,\ e_{41} = 2,\ e_{51} = 4,\ e_{61} = 0;$$

j = 2

$$e_{12} = 3,\ e_{22} = 4,\ e_{32} = 3,\ e_{42} = 3,\ e_{52} = 3,\ e_{62} = 0;$$

j = 3

$$e_{13} = 4,\ e_{23} = 3,\ e_{33} = 1,\ e_{43} = 4,\ e_{53} = 0,\ e_{63} = 0;$$

- **Output data:**

$CVH_1 = 2,46$; $CVH_2 = 3,13$; $CVH_3 = 2,51$.

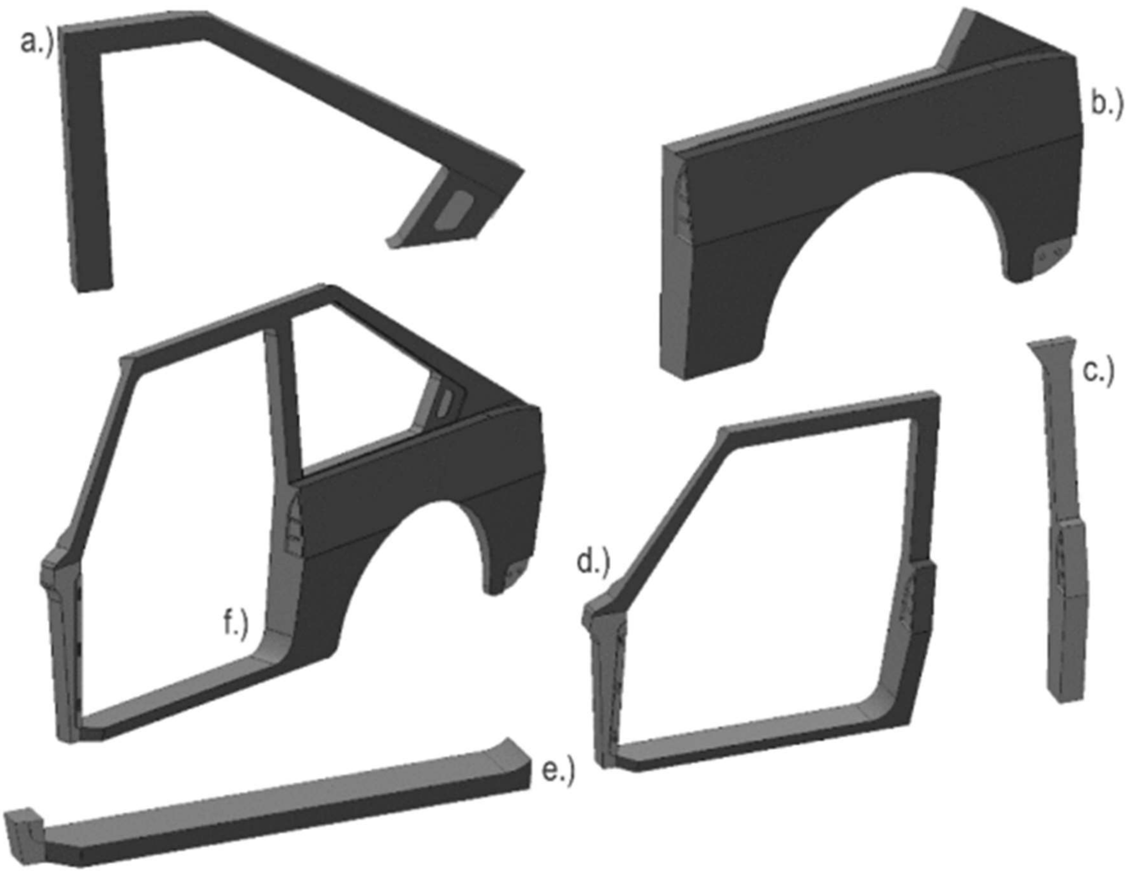
The overall weighted value CVH2 represents the best concept (the second variant, the car door frame is made from aluminium).

- **Exact assessment:**

The basic input data are given above. The other data, during the interactive procedures between CoDe-09 system, and the operator, for their multiple number and specific character are not given here.

The obtained results are:

SMP(1) = 11 712,48 mP,
SMP(2) = 7 665,34 mP,
SMP(3) = 17 978,40 mP.



The legend: a.) left rear upper door window frame, b.), left rear bottom frame above the wheel, c.) left centre pillar bracing, d.) left front door frame e.) left front door sill, f.) complete left car door frame

Fig. 287 A passenger car door frame

The best concept, according to the approximate and exact assessment is the same, but the car door frame made from steel, according to the exact assessment, represents environmentally more suitable concept variant than the third one.

Results and Conclusion

The evaluation is based on the response of firms and other users of the CoDe-09 software.

- The applied methodology is interesting and seems to be well developed.
- If the CoDe-09 software user is a well-qualified designer constructor the approximate result is sufficient, and it is not necessary to apply the exact assessment, because the results obtained are the same.
- Product designers have a feel for the responsibility if they apply the CoDe-09 software, and its approximate version.
- It is very motivating to learn how to do something in the conceptual phase for the environment rather than always to have a bad feeling because you as a product designer support materialization.
- The software product CoDe-09 has been successfully applied in many institutes and factories. At the present time, it is widespread commercially.

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LIST OF FIGURES

LIST OF TABLES

ENVIRONMENTAL ENGINEERING

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