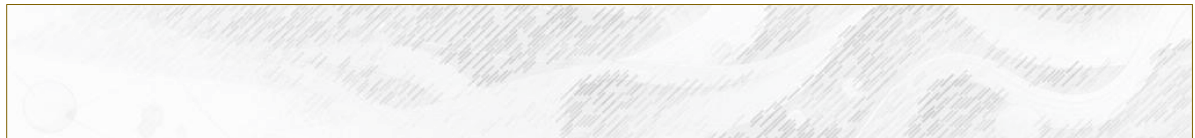




Methodology for carrying out excursions on  
water management facilities  
**wastewater**



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## Cover sheet

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# Od kohoutku do záchodu

Tento projekt je financován Evropskou unií v rámci Národního plánu obnovy.

Projekt cílí na zlepřování kvality odborných exkurzí a odborných přednášek či demonstrací v oblasti vody. Primárně se zaměřuje na poskytnutí podpory a materiálů pro učitele, odborníky a pracovníky vodohospodářských společností, kteří provádějí exkurze.

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## General introduction

Welcome to the methodology for excursions to wastewater treatment plants (WTP). Wastewater treatment plants are extremely important for the protection of the environment and human health. This methodology will provide you with a general introduction and guidance on how to present a wastewater treatment plant as a fascinating place where the story of water, substances and energy, but also the people who work there, unfold. The goal of the excursion is not only to familiarize students with the basic principles of wastewater treatment, but also to motivate them to treat water and the environment responsibly.

The methodology is created so that it can be used at larger and smaller wastewater treatment plants. In the chapter Description of technologies, you will find an overview of cleaning technologies, from which you can choose only those that you have in the given location and include them in the excursion.

- 1.1.1 The methodology is designed for primary and secondary school students, or even for the most curious excursion participants. Color-coded paragraphs are used to distinguish different levels.

### Level Legend:

*Elementary schools - due to the teaching of chemistry and other subjects, pupils in the second grade of elementary school (ie approx. 11-15 years old) are primarily counted.*

*Secondary schools - approx. 15-19 years old from various schools (gymnasium, industrial schools, apprenticeships...).*

*Inquisitive - useful, for example, for field trips to elective seminars in chemistry or the environment in high school graduation years or for youth technical clubs and other institutions of interest and informal education.*

- 1.1.2 The excursion can be guided from different points of view, which you can combine and thus create a comprehensive view of the issue of wastewater treatment. We have prepared three for you – the story of water, the story of substances and energy, and the story of people.

### The Story of Water:

- 1.1.3 Begin the tour by introducing the wastewater treatment plant as the place where the story of water takes place. Explain to students that the wastewater we produce in our homes and industries goes to a treatment plant where it is treated and returned to nature. Introduce them to the process of water purification and explain its importance for environmental protection.

### The story of matter and energy:

- 1.1.4 Next, focus on the story of substances and energy that are recycled at the wastewater treatment plant. Explain to students that a treatment plant uses a variety of technologies and processes to remove impurities from wastewater. Show them how valuable substances such as phosphorus or nitrogen are obtained from wastewater, which are further used, for example, in agriculture. Also mention the use of energy obtained from wastewater, for example for heating a treatment plant or the production of renewable electricity and biomethane.

### People's Story:

- 1.1.5 Let the students also know the story of the people who work at the wastewater treatment plant. Introduce them to the different professions and occupations found in the treatment plant, such as chemists, technicians or operators. Explain the importance of their work for the protection of the environment and how they take care of the proper operation of the treatment plant.

### How to prepare for the excursion?

In order for the excursion to interest the visitors and at the same time take away knowledge from it for the next life, it is necessary to prepare for it and adapt the interpretation to the audience, its age, experience and interests. At the same time, it is a good idea to make the excursion as interactive as possible (which makes you different from other explanatory classes, e.g. tours of castles and chateaux). Remember that excursions with a longer theoretical part are more suitable for secondary school students. Younger participants tend to have a significantly lower level of concentration, which is why it is necessary to think as practically as possible, even at the cost of a smaller volume of transmitted information.

- **In particular, it is good to know:**

**How many visitors will come?**

- Not only with regard to the interpretation, as attention decreases as the number of participants increases, but also with regard to the technical arrangement – will everyone hear me? can we fit in individual stations? or to the control room? If you have enough guides, don't be afraid to split the group into several smaller groups.

**How old are they and what school are they from?**

- Students of an industrial school focused on automation will be interested in different information than students of a humanities-oriented grammar school, and those in turn will be interested in different information than future nurses; the excursion will look different for 6th grade elementary school students without knowledge of chemistry.

**What is the purpose of the excursion?**

- Whether to primarily convey theoretical knowledge about cleaning processes, or whether a theoretical lesson has already taken place at school and the aim of the excursion is to show the acquired knowledge in practice; or present the job description of employees (career in the water sector).

**How much time do you have for the excursion?**

A typical time is two teaching hours, i.e. roughly 1.5 hours; however, it depends not only on the age of the participants, but also on the distance between the school and the cleaning plant building - this aspect of the tour must always be agreed in advance with the teaching staff.

- **It is a good idea to prepare general information about wastewater treatment in advance, for example:**

**How much water will flow through the wastewater treatment plant in a rainless state per second, per day, per year? How much water can the WWTP clean during a heavy rain (i.e. when its capacity is filled)?**

<p><b>For a better idea, it is advisable to convert the values into some more accessible units, see the table below.</b></p> <p>Unit</p>	<p>Volume</p>
<p>Olympic pool (depth 2.5 m)</p>	<p>3 125 m<sup>3</sup></p>

rural pond	on the order of thousands of m <sup>3</sup>
railway tanker	46–90 m <sup>3</sup>
tank on chassis T815	9 m <sup>3</sup>
tank on V3S chassis	3,5 m <sup>3</sup>
bath	100–200 l
bucket	12 l
garden watering can	5 l

### What is the proportion of sewage, ballast water and water from industry?

#### From which parts of the city/municipality do you treat wastewater to a specific WWTP?

- Whether the entire territory of the city/municipality is drained to this WWTP or are some areas treated differently. Or whether there is another nearby area connected to a specific WWTP.

#### How many people/households do you treat wastewater from?

- Of course, you don't need an exact number, rather an order of magnitude for an idea.

#### How long is the sewer network and what material is it made of?

- Again, it is possible to zoom in using, for example, the distance from the excursion site, or the city/village center to city XY; how many gas stations and other interesting objects are there on it.

#### How much electricity is needed to clean wastewater?

- You can compare with consumption at home - the average consumption of electricity in the Czech Republic in 2023 for 1 household was 3,500 kWh/year, (usual water consumption at a treatment plant per 1 equivalent resident is around 50 kWh/EO).

#### Into which watercourse does the treated wastewater flow?

In addition to the name of the watercourse, it is possible to add other information such as:

- What is the quality of the water in the stream? What is its flow rate? What part of the flow is the effluent from the treatment plant?

#### How much does it cost to purify 1 liter of water?

- **Think about:**

#### Where will you take visitors?

- With regard to their safety, traffic safety, space capacity, time allowance for the tour and the distance between individual locations.

#### What main information should participants take away from the excursion?

- It is not advisable to switch their powers here, it is enough if they take away 3-4 key pieces of information.
- **What will you roughly call them together with the time allowance for individual stops?**
- **What will you show and demonstrate to them that they can try for themselves in your conditions?**
- **What might they ask you?**
- **What did you not understand at their age and would you like to understand?**

#### What will you ask them?

In order to make the tour more interactive and at the same time to find out the initial state of knowledge of the participants about the given issue.

- **Ensure and prepare in advance:**
- **Necessary documents required by the operator of the facility (for example, health and safety, name list of participants).**
- **Necessary safety equipment, if needed (safety vests, helmets, gloves,...).**
- Worksheets for visitors (after agreement with teachers).

Demonstration aids.

- For example, equipment for taking water in individual technological stages, a sludge sedimentation cylinder, etc. We also recommend preparing a simplified technological diagram, map or aerial photograph of the area (to either distribute it to participants or, if necessary, regularly show the current location on a large format).
- **Small rewards for visitors, if available (for example company pens, candies...).**

Possibility to use the toilet and wash hands after the excursion.

## 1.2 Own excursion

### health and safety

A short field trip safety and health training is the first mandatory part of every field trip. Please do not underestimate this part, even though it may seem redundant or unnecessary.

During the OSH training, use your company's internal guidelines, or you can use the appendix of this methodology, which contains a simple overview of what to familiarize the excursion participants with.

Furthermore, it is advisable to send an introduction to health and safety in advance and to request a signed list of names of participants with confirmation that they have been familiarized with health and safety in advance and to do only a short refresher on health and safety points before the excursion.

At the beginning of the excursion, it is appropriate to emphasize that participants will not be able to eat, drink or leave the group during the excursion. Before the start, it is advisable to leave time for participants to have a quick snack or visit the toilet.

## Importance of urban wastewater treatment

? Question: Why do we purify water?

💡 Answer:

In the past, sewers flowed directly into local rivers, streams, ponds, seas, etc., the goal was to get rid of the wastewater as quickly as possible. However, the pollution of waterways often resulted in the destruction of their ecosystems, diseases and odors spread through the water, and it was not possible to use the water for necessary activities.

Water purification is especially important with regard to the use of the river downstream from the wastewater treatment plant. If we did not clean the wastewater sufficiently, there would be a threat to the health of the public. The water under the wastewater treatment plant can be used for recreation, as a source of drinking water or for irrigation. Water purification prevents the transfer of germs, bacteria and chemicals that could cause disease, infection and promote the process of eutrophication.

**ZŠ: *Cleaning urban wastewater is of fundamental importance for the protection of the environment and human health. This issue has accompanied mankind since ancient times, when the first civilizations struggled with the effects of polluted water on their inhabitants.***

**SŠ: *In ancient Rome, there was an elaborate system of sewers and sewers that carried wastewater away from the city. Nevertheless, diseases such as cholera and dysentery caused by contaminated water continued to spread. Historically, these epidemics have claimed millions of lives and led to the need to solve the problem of sewage in a more efficient way.***

*The turning point was the discovery of microorganisms and their role in the decomposition of organic substances in the 19th century. This has enabled the development of biological wastewater treatment plants that use natural biological processes to remove pollutants. The first modern wastewater treatment plant was commissioned in Britain in 1892.*

*Today, wastewater treatment is absolutely necessary to maintain the quality of water resources and protect the environment. Discharge of untreated sewage into rivers, lakes and seas would have devastating effects on aquatic ecosystems, killing fish and other aquatic life and making it impossible to use the water for recreational purposes or for the production of drinking water.*

*An example can be the situation in India, where the Ganga River is one of the most polluted rivers in the world due to the discharge of untreated sewage from cities and industries. This pollution not only threatens local ecosystems, but also poses a serious health risk to the millions of people who depend on the river.*

*On the contrary, proper wastewater treatment enables the safe discharge of treated water back into waterways without polluting them. In this way, aquatic ecosystems are protected, the quality of drinking water is preserved and the risk of the spread of diseases is reduced. Wastewater*

*treatment also enables the recycling and reuse of valuable resources such as nutrients and energy contained in wastewater.*

*It is clear that the treatment of urban wastewater is a key factor for the sustainable development of our cities and municipalities and the protection of the environment for current and future generations.*

***Curious: In the summer of 1858, the so-called Great Smell appeared in London. At that time there were about 2 million people living in London and the number was constantly increasing. Originally, they went to the toilet in potties that were emptied into cesspools, which were exported outside the city to the fields, and their contents were used by farmers as fertilizer, but also for the production of gunpowder. However, as the number of people increased, the sumps were no longer enough, and flush toilets appeared, so the amount of wastewater increased further. The management of London finally decided that the sewage would initially be discharged through the storm drains into the Thames. The river turned into a drain. Everything from the contents of toilets to dead dogs, decaying food and industrial waste, including animal parts from slaughterhouses and chemicals from tanneries ended up in it. In addition, the summer of 1858 was extremely hot, so the waste in the river decomposed even faster than usual. The waste in the river was "literally boiling and fermenting" and the stench was such that people vomited and passed out in the streets, Queen Victoria canceled river cruises and Parliament could not sit. Not even 250 tons of chlorinated lime poured into the river helped. In the end, it was decided to build a new, complete sewer system with a length of 1,800 km, draining water under the city (construction began the very next year). After its completion there was never another cholera epidemic in London.***

? Question: What is eutrophication?

💡 Answer: Eutrophication refers to the process of enriching water with nutrients, especially nitrogen and phosphorus contained in urine and feces. A distinction is made between natural and unnatural eutrophication (caused by human activity). As a result of a large amount of nutrients, plankton and also cyanobacteria (water bloom) multiply in the water, resulting in a decrease in oxygen in the water, which is manifested by its rotting, the death of fish and other organisms living in the water.

In most countries, there are legislative requirements for water quality and water treatment that must be followed. These regulations are designed to protect human health and the environment.

## Development of wastewater treatment

It is possible to start the excursion with a short historical introduction of how wastewater treatment developed in the given locality. The aim of this section is not to go into great detail, but only to point out the important milestones. Information on local developments can be found in the company archive or the archive of the relevant municipality. Furthermore, it is advisable to inform visitors if the treatment plant will develop in the following years, for example, increase in size based on the increasing number of inhabitants.

If the historical information is not available, you can use the following paragraphs for a short introduction, which deal with the general development of wastewater disposal and sewage treatment.

*Elementary school: We recommend not burdening these students with exact dates, but rather to mention only the biggest changes that have taken place at the treatment plant during its existence.*

*Secondary school: With these pupils, you can already go into greater detail, but try to intersperse the data with various interesting facts and stories, for example from the reconstruction.*

### General history of the cleaning industry in the Czech Republic

The wastewater treatment process spread to the Czech Republic from England, where the first treatment plants (mechanical or mechanical-chemical) were established at the end of the 19th century. These treatment plants also include the Old Wastewater Treatment Plant in Prague in Bubeneč. Interestingly, this cleaning plant is located underground.

At the beginning of the 20th century, the activation process was discovered in Manchester, England. Two British chemists (Edward Arden and William Lockett) were conducting experiments with aeration of wastewater and found that a suspension was formed in the water, which shortened the time of wastewater treatment. They called this suspension activated sludge. The spread of this discovery was slowed down by the First and Second World Wars, and the process was not more widely practiced until after the Second World War (after 1945). The first wastewater treatment plant with biological treatment using an activation process was the Modřice WWTP (1961). This process was subsequently used in Prague in 1968.

## 1.2.1 The story of water

### wastewater source

**Interpretation tip:** Here there is a lot of room for the participants of the excursion to think. What all goes to the dry cleaner? From where? Where is wastewater generated at home (toilet, shower, dishwasher, washing machine, etc.) and in what quantity? What are the other sources of wastewater in the vicinity (industrial enterprises, agriculture, hospitals, schools, restaurants,...)? What would happen if we did not treat the wastewater and discharged it directly into the river? When mentioning organic pollution, the number of equivalent inhabitants can be given. In conclusion, it is appropriate to say how residents pay for wastewater treatment.

? Question: Where is the wastewater taken?

💡 **Answer:** Wastewater is water that we have used that is now polluted. This water comes from our homes (toilet, dishwasher, washing machine,...), factories, hospitals and offices. This also includes rainwater that did not soak into the ground during a storm or heavy rain, but ran down the drain. All this water drains into a pipe that takes it to a wastewater treatment plant to be cleaned so it can be returned to nature.

**ZŠ:** Discuss in general what are the sources of wastewater in the household - where do they think they have the most water consumption and what is found in the wastewater (water, solid particles, floating particles, oils, fats).

- **Inquisitive:** According to origin, we divide wastewater into:
- sewage wastewater (or sewage) - comes from households and social facilities

*industrial wastewater - comes from industry (from factories)*

? Question: What does wastewater contain?

💡 **Answer:** Water pollution is made up of dissolved and undissolved substances. Solutes can be biodegradable (e.g. monosaccharides) or non-biodegradable (e.g. azo dyes). Dissolved substances found in wastewater also include dissolved inorganic salts. Undissolved organic substances in wastewater are again divided into degradable (starch, cellulose) and non-degradable (plastics). Undissolved inorganic substances include, for example, sand and gravel. The inflowing water also includes things that are more like municipal waste. However, they do not belong in the sewer and should not enter it at all. Furthermore, there are bacteria and microbes in the water that can cause diseases.

**Interpretation tip:** Use this opportunity to discuss with the participants what does not belong in the waste. It is usually advisable to have this discussion in a place where you can see the flowing water and it is possible to immediately point out objects that do not belong in the wastewater. It is also advisable to ask about their practice at home and perhaps also about what they do with oils and fats.

*Primary school: For older pupils, you can ask guiding questions directly about the chemical composition of wastewater - what organic or inorganic substances are found in wastewater.*

? Question: How much wastewater does a person produce?

💡 Answer: The quantity and quality of wastewater produced by humans can vary. For the purposes of designing treatment plants, a unit called equivalent population (EO) was created, which reflects the average quantity and quality of wastewater produced by one resident in one day. The amount of pollution produced by one EO corresponds to:

1 EO = 120-150 l/d wastewater

1 EO = 60 g/d organic substances (BOD5) 1 EO = 11 g/d Ntotal 1 EO = 2.5 g/d Ptotal

BOD5 (biological oxygen demand) is an analytical method for the determination of organic substances that are subject to biochemical decomposition under aerobic conditions. In other words: biological oxygen demand expresses how much oxygen bacteria need to remove organic pollution in wastewater.

As a rule, industrial buildings are also connected to the wastewater treatment plant. To estimate pollution, conversion tables are created, with the help of which we can calculate the pollution corresponding to equivalent inhabitants.

For example:

The production of 1 ton of beets in a sugar factory corresponds to 45-70 EO.

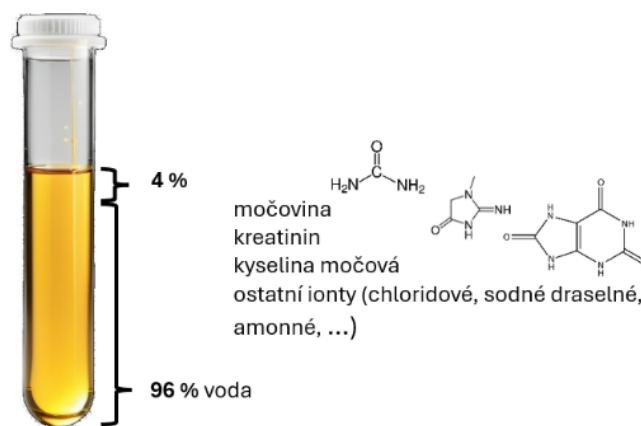
The production of 1 m<sup>3</sup> of beer corresponds to 150-350 EO.

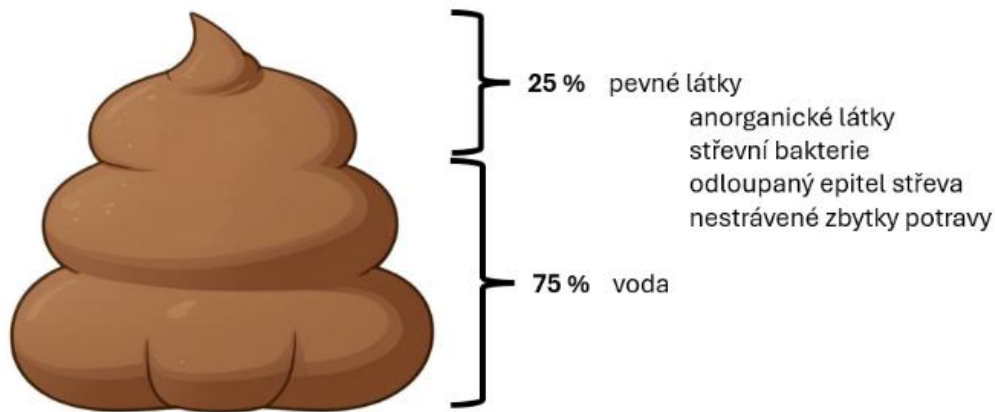
Washing 1 ton of laundry in a laundry corresponds to 350-950 EO.

? Question: What substances do human urine and feces contain?

💡 Answer: Urine and feces are waste products of human metabolism. Urine is produced by filtering blood in the kidneys and stool is formed in the large intestine.

The composition of human urine and stool is shown in the following figures. From the point of view of wastewater treatment, urine is an important source of nitrogen. On the other hand, faeces are a source of phosphorus and organic substances. Organic substances come from the remains of food that is not completely digested in our body.





? Question: Does the composition of wastewater differ in different cities/locations, or is it the same everywhere?

💡 Answer: wastewater from households and social facilities (sewage) has approximately the same composition. As for industrial wastewater, the composition here is very dependent on the type of industry. The nature of the pollution strongly influences the technology used at the WWTP.

? Question: What does and does not belong in the toilet?

**Interpretation tip: In this section, it is advisable to educate visitors about what does not belong in the sewer, or what should not be flushed down the toilet, kitchen sink or sink at home.**

- 💡 Answer: Sewage does not include:
- food leftovers
- waste from kitchen shredders
- fats and oils
- hygiene supplies – wet and cosmetic wipes, cotton buds, disposable diapers,...
- municipal waste

chemical residues, or perhaps mercury

**Curious: Christmas is a critical time when it is a bad habit of people to pour huge amounts of oil into the garbage. Oil belongs in oil containers or in the collection yard.**

? Question: Why don't these things belong in the sewer?

💡 Answer: Because they can damage or clog sewer pipes and equipment at the wastewater treatment plant. For example, fat settles on the walls of the sewer, and other impurities (napkins, hygiene items,...) are then caught on it. This can lead to complete clogging of the pipes, and the wastewater then has nowhere to drain. It's not just about the pipes carrying wastewater to the treatment plant, blockages can also occur in the sewage pipes in your home. In such a case, the remedy is very complicated and unpleasant. Or, in the case of food scraps, they can support an abundance of rats in sewers, which can carry disease and are generally unwelcome guests in cities and homes, which then need to be dealt with by sewer extermination. In the case of hazardous substances and chemicals, there is a risk of damage to the technology of the treatment plant, especially the biological process, as well as endangering people working on the sewage system and at the treatment plant.

*Inquisitive: The most famous case of sewer blockage with grease and other sewage waste is from London in 2017. The accumulated material measured 250 meters and weighed 130 tons. It took 9 weeks of work to remove it. In English, the name "Fatberg" has even been coined for this "deposit", which was created from the word "fat" - fat and "iceberg" - iceberg, in Czech it could be called "tukovec".*

## The path of water to the wastewater treatment plant

**Interpretation tip:** Here it is good to know where the wastewater flows to your treatment plant (from which cities/local districts/municipalities), how much it is (per year and per second), how many people it comes from, how long is the sewer network that brings the water, how long it takes for the wastewater to flow to the treatment plant. You can make a poll among the visitors about whose wastewater flows here, where the wastewater from their school flows, and so on.

? Question: How is wastewater discharged to the wastewater treatment plant?

💡 Answer: wastewater from buildings is discharged through pipes that open into larger pipes forming a sewer network. A sewage network is a transportation system that transports wastewater from the place where it originates to the place where it is treated. The sewer network is underground, but we can tell where it goes by the round manhole covers on the street.

The sewage system, or sewer network, can be designed in different styles depending on whether sewage and rainwater are drained together. A unified network where, as the name suggests, all wastewater is removed regardless of its type, i.e. wastewater is removed together with rainwater. A sewer network where wastewater and rainwater are discharged via separate routes and do not mix is called a separate system. Wastewater is discharged to a wastewater treatment plant, while rainwater is discharged, for example, into a watercourse.

The disadvantage of a unified sewer network is its overload during heavy rains. The sewage network is designed for the maximum amount of wastewater that it is capable of holding, and the same is true of the wastewater treatment plant. If the capacity of the sewage network or wastewater treatment plant is exceeded, the wastewater that is "extra" falls through the relief chambers directly into the water course. This untreated wastewater, which contains, for example, wastewater from toilets, pollutes the waterway.

An option to reduce the amount of rainwater that gets into the sewer system is the targeted trapping of rainwater. Rainwater that would flow down the sidewalk, road or, for example, the roof into the canal, is diverted so that it reaches the soil, where it can be used by plants.

*Elementary school: Find out how far the school they came from is and compare it with the length of the sewer network. Let them guess the time it will take for the wastewater to arrive at the treatment plant. Discuss where and why manholes from sewers (main roads) are located. It is possible to ask about various objects and devices of sewage networks that they have encountered - most often they will mention a channel, you can tell them that they are correctly called a drain or a gula.*

**Inquisitive:** On the streets, we can most often meet two objects, which are commonly referred to as a "channel". You may have noticed that some "channels" have a grate and allow water to flow in. These are sewer drains, also referred to as gula. But some hatches have either only tiny holes or no holes at all. These are sewer manhole covers that allow access to sewer network objects. They usually hide a connection, some change in the direction of the sewer (break shaft), or it is an inspection shaft that is placed regularly to ensure access to the sewer and its cleaning with pressurized water and special equipment.

? Question: Why does the sewer smell?

💡 Answer: The decomposition of organic compounds in the sewage network produces gases that cause a strong odor. The decomposition of organic compounds occurs in places where there is a low flow of wastewater or an insufficient slope of the sewer network. The decomposition of organic compounds containing sulfur produces sulfane, which is a poisonous gas. Sulfane smells like rotten eggs.

Air flow in the sewer system also plays a significant role. If there is enough oxygen in the sewage, putrefaction occurs to a minimum.

During heavy rain, all settled dirt is flushed into the sewer network. The first wave of wastewater that arrives at the treatment plant is therefore very concentrated.

*Elementary school: You can give the students space and ask if they have ever smelled the smell of sewage and what they would compare it to.*

*SŠ: Sulfane already smells at concentrations of 0.5 ppm (particles per million). Here you can ask the pupils for a hint - how many molecules do they think there must be in the sewage for us to smell sulphane? This question will get students thinking and introduce them to the new units of ppm that are often used to express concentration in the US.*

Sulfane therefore smells from the concentration, when there is one molecule of sulfane in the air for two million molecules of air (oxygen + nitrogen). Or at a content of 0.00005% sulfane in the air. So 0.5 ml of sulfane in 1 m<sup>3</sup> of air.

? Question: Do any animals live in the sewers?

💡 Answer: There are rats in the sewage network, by throwing leftovers into the waste we provide them with a source of food. For this reason, they can even proliferate in some cities. In the spring and summer months, their extermination takes place, when poisonous traps are placed in the sewer network to keep the rat population at a reasonable level. Hubex is used to exterminate rats - food traps suitable for humid environments. These contain, for example, breadcrumbs, meal, corn, chocolate, fat and the active substance anticoagulant.

A rat is often mistaken for a mouse. The mouse has lighter fur, is larger, has a shorter tail than its body, and likes a moist environment. While the rat has up to black-gray fur, it is smaller, but its tail is longer than its body, and it does not like damp environments.

? Question: What is the temperature in the sewer?

💡 Answer: The temperature of sewage water in the sewer depends on the season, it ranges from 8 to 20 °C.

? Question: What shape is the sewer?

💡 Answer: The transverse profiles of sewers can have different shapes. The basic shape is circular. Another shape is the oval shape, which is ideal for uniform drains with fluctuating flow. The mouth profile is used when there is insufficient overburden height.

? Question: What materials is the sewer net made of?

💡 Answer: The sewer network must be built from materials that are resistant to abrasion, corrosion, chemicals and microbial action. Stoneware, concrete, cast iron, basalt, sewer bricks (bell blocks) or plastic are used to build the sewer network.

**1.2.2 Inquisitive: In the construction of sewers, special ceramic bricks, the so-called bell bricks, were previously used. These are very hard bricks made of special clay, which are fired twice in a brick kiln in a reducing flame. Old stocking nets can be seen, for example, in Rome (Forum Romanum) or in Prague, where the Foreigner's Entrance is opened several times a year (at the Old Town Astronomical Clock). Here it is possible to enter the connecting chamber, which was built more than a hundred years ago.**

## wastewater treatment plant

**Interpretation tip: This part needs to be compiled so that it corresponds to your specific cleaning plant. In the following paragraphs, you will find generally described steps for wastewater treatment. For a more specific explanation of the individual technologies that are at your treatment plant, you can use chapter 3. Description of WWTP technologies. This chapter is designed as a so-called catalog, from which you can choose only the parts that suit you in the interpretation of the excursion.**

? Question: Where and how is wastewater cleaned?

💡 Answer: At the wastewater treatment plant.

The sewage network brings the wastewater to the wastewater treatment plant, where its treatment begins. Small amounts of pollution can be cleaned by nature itself, this process is called self-cleaning. The wastewater treatment plant uses the same principles as nature, only we create optimal conditions for them to take place as quickly as possible.

The way in which the water will be purified varies according to the specific location, depending on the technologies the treatment plant is equipped with, the type of wastewater that flows in, and also how much water is being purified.

If possible, the wastewater flows through the treatment plant by gravity, i.e. by gravity drop. This is particularly advantageous in terms of electricity consumption. We will save energy that we would otherwise use to operate the pumps.

First, we need to remove large objects that float in the water or are on the bottom. This can be, for example, stones, sand, leftover food or wet wipes. These objects are removed in such a way that the water flow is slowed down and the dirt settles on the bottom (gravel trap, sand trap) or is caught on grates or sieves (combing room). In addition to the above-mentioned objects, undissolved organic substances are also present in the water, which are captured in sedimentation tanks. This settled material, called primary sludge, is pumped out for further processing into the sludge management. We then have pollution left in the water, which is not visible to the naked eye, i.e. it is dissolved in the water.

Dissolved pollution can remove bacteria and other microorganisms from the water to a certain extent (activation tank). Technically, the collection of these bacteria is referred to as activated sludge, and the cleaning process is called biological cleaning.

**Interpretation tip: It is advisable to adapt the depth of the description of biological wastewater treatment to the target group. Below we offer variants according to the level of listeners.**

**ZŠ:** *At the wastewater treatment plant, we keep these bacteria like animals in a zoo. We take care of them by creating suitable conditions for them to live and by giving them wastewater as food. We breed several types of bacteria here. What conditions do they need for life? It depends on their nature, some need a lot of air to live, while others appreciate it when they don't have air at all. Satisfied bacteria live together and create such small towns, which we refer to as flakes, multiply and their population grows.*

**SŠ:** *Activated sludge consists of microorganisms, which we maintain in the required quantity at the wastewater treatment plant. Microorganisms in activated sludge include bacteria, protozoa (dung beetles, molluscs, crustaceans), metazoa (rotifers, nematodes, worms) as well as molds, fungi and yeasts.*

**Interpretation tip:** *Here it would be good to show the children some pictures of the mentioned microorganisms or a video, for example on a mobile phone, so that it is not just a long explanation. In addition, you can encourage children to ask their biology teacher at school for additional information.*

*Bacteria transform pollution from wastewater through their metabolism, i.e. the pollution serves as food for them. We distinguish several types of bacteria according to their metabolism. Bacteria oxidizing the organic substrate (organotrophic), bacteria oxidizing ammonia nitrogen and nitrite nitrogen to nitrate nitrogen (nitrifying), bacteria reducing nitrate nitrogen to gaseous nitrogen (denitrifying) and bacteria that accumulate a higher amount of phosphorus (poly-P) in their cells. Individual types of bacteria need suitable oxygen conditions for their metabolism - oxidizing bacteria need oxygen, reducing bacteria, on the other hand, need conditions practically without oxygen. Therefore, the conditions in the wastewater treatment plant change so that each type of bacteria can do its job. Bacteria live together in flakes, multiply and their quantity or concentration in the system increases.*

**Inquisitive:** *There is a constant fierce competition for resources ("food") between the individual species of organisms in the activated sludge. The bacterium that can obtain the most energy under the set conditions will reproduce the most, and thus begin to dominate and displace the less successful ones. Different groups of bacteria that break down different types of pollution quite often consider completely different conditions to be ideal. In addition, most bacteria can process "food" through various metabolic pathways. For example, in the presence of oxygen, they remove organic matter using so-called aerobic respiration, but if oxygen is not available, they can switch their metabolism to the much less advantageous denitrification. Organisms always "choose" the process from which they get the most energy under the given conditions. At treatment plants, however, we often also need bacteria that carry out few nutritious reactions and therefore grow slowly. We try to create the best possible conditions for them and pamper them. A typical example is nitrifying organisms, for which we build regeneration tanks with an excess of oxygen, where they can "rest" and "digest" stored substances.*

*Activated sludge organisms are truly microscopic, their size ranges from tens to units of micrometers. For reference, one micrometer is one millionth of a meter. These tiny organisms can only ingest small food molecules. However, most pollutants in water are much larger. So how can bacteria digest these larger impurities? To do this, bacteria use special chemicals called exoenzymes. Enzymes are substances that speed up or slow down chemical reactions. In the case of activated sludge bacteria, a process called hydrolysis helps them. The prefix "exo" means that these enzymes are released by the bacteria out of their body into the environment. It is similar to a spider injecting its digestive juices into a fly caught in its web. Instead of a fly in the cobweb, in this case we have wastewater in the tank. Long pollutant molecules are split into smaller molecules with the help of exoenzymes. These are already small enough for the bacteria to accept them inside their cells and further process and digest them there.*

Then the bacteria continue to settling tanks, where they need to be separated from the purified water. Bacteria in flakes (or in their "towns") slowly sink to the bottom of the tank. We have to put most of the bacteria back into the process to clean the newly inflowing wastewater. This is a continuous process and we cannot afford to wait for a new full-fledged culture of microorganisms to grow. And because microorganisms multiply really quickly, some of them are removed from the process due to "redundancy" and pumped to the sludge management for further processing.

At the top of the settling tank is cleaned water that spills over the edges or into a submerged drain pipe and flows away from the treatment plant back into nature (for example, into a watercourse).

***Inquisitive: Talking about activated sludge only about bacteria is a gross oversimplification. In fact, activated sludge is a whole microcosm with countless different types of bacteria that dominate it, but in addition to them, higher microorganisms such as various protozoa, metamorphs, ciliates, helminths, rotifers or mites and, under suitable conditions and in certain places, also photosynthesizing organisms such as algae are found in activated sludge.***

**Interpretation tip: Here it is good to warn visitors that this water is not drinkable! And it is appropriate to explain why.**

? Question: Is the water flowing out of the wastewater treatment plant potable?

💡 Answer: The water purified in this way is clean enough not to pollute the stream with increased amounts of organic substances, nitrogen and phosphorus, but it is not drinkable! It is similar to drinking water directly from a river or puddle. Bacteria that could cause digestive problems need to be removed from this water.

? Question: Where is drinking water produced?

1.2.3 💡 Answer: At the water treatment plant. Which is another device in which drinking water is produced from water of natural origin.

### Effluent quality and control

**Tip for interpretation: There is space to mention which watercourse the purified water flows into and what, for example, its quality class and whether the flow in the stream is sufficient.**

If you have mobile analytics available (pH probe, droplet tests,...), you can have visitors check the quality of the effluent.

? Question: How do we find out that the treated wastewater is OK?

💡 Answer: Runoff quality is assessed in different ways. The easiest is to use the senses (sight, smell) - experienced workers remember how the drain "looks" normally, if something changes (color, transparency, amount of flakes, smell), they search for the cause. Another aid are online probes and analyzers (for example, measuring ammonia, nitrates, turbidity, phosphates,...), but they are very expensive (more than tens of thousands to hundreds of thousands of CZK per piece), so they are used at really large treatment plants. Portable probes and "droplet tests" can also be used, where the color is compared with a color scale. The most accurate is the determination of substances in the laboratory.

? Question: What quality should the treated wastewater have?

💡 Answer: The quality of effluent from the treatment plant is subject to legislative regulations. Czech regulations correspond to the legislation of the European Union. The limits are set both for the limits of individual compounds and for the efficiency of removal of individual substances at the wastewater treatment plant. The level of limits is graded according to the size of the treatment plant, the larger the treatment plant, the stricter the limits. The exact limits for treatment plants are determined by the water authority, and each treatment plant may have slightly different limits. The quality of the purified water flowing out is subject to independent checks by the authorities, for example the Czech Environmental Inspectorate, water authorities, etc. If the limits are exceeded, the operators of treatment plants pay fines.

In order to measure the amount of treated wastewater, flow measurements of treated water are installed at the outlet from the treatment plant. Most often, a Parshall trough with a level sensor is used to measure water flow.

In some water courses (rivers, streams), the effluent from the treatment plant is responsible for a large part of the flowing water. There are also cases when the quality of the effluent from the treatment plant is higher than the quality of the water in the waterway. The limits set by the water authority are modified with regard to the use of water downstream (recreation or drinking water abstraction).

**ZŠ: Do not burden these pupils with the details of legislative regulations, it is sufficient to say that the purified water must meet certain parameters of the concentration of carbon, nitrogen and phosphorus before it flows into the river, and a large amount of undissolved substances must not float in it.**

**Secondary school: We can explain to these pupils in more detail how sampling and measuring water flow works.**

**Inquisitive: If someone is very interested in finding out the limits on wastewater discharge, you can refer them to Decree No. 401/2015 Coll. An interesting feature in the legislation is the introduction of two limits "m" and "p". The symbol "m" indicates the maximum non-exceeded limit, and the symbol "p" is the permissible limit, which can be exceeded in a certain amount of runoff samples to a permissible extent.**

? Question: What are the options for further purification to make the water even cleaner?

💡 Answer: In certain cases, water is processed by so-called tertiary treatment (mechanical and biological treatment can be referred to as primary and secondary), which already includes specialized methods designed to adjust specific water quality indicators characteristic or significant for the given treated water or recipient.

Tertiary treatment is increasingly applied at wastewater treatment plants, due to gradually tightening limits that cannot be met by using only primary and secondary treatment.

Tertiary cleaning methods include disinfection, membrane technologies, chemical precipitation of phosphorus or filtration through a layer of activated carbon. In other words, these are waterworks methods.

**ZŠ: If your treatment plant does not have any of the tertiary treatment technologies, then it is enough to say at the end of the drainage facility that the requirements for treated wastewater will gradually increase and for this reason other technologies will appear at the treatment plant.**

**1.2.4 Curious: In 2024, a new European Union directive on wastewater treatment will be published, which will dramatically tighten the limits on nutrients in discharged wastewater.**

## The future of cleaning

? Question: What will wastewater treatment look like in the coming years and decades?

💡 Answer: At some treatment plants in the world, tertiary and quaternary treatment already exist, i.e. the next level of cleaning, when high-quality water leaves the treatment plant. However, this water no longer only goes into the waterway. Due to its high quality, its recycling (reuse) is possible.

? Question: What can recycled water be used for?

- 💡 Answer: Some of the possible uses for recycled water include:
- irrigation and agriculture – irrigation of gardens, urban greenery, golf courses and agricultural areas
- industrial applications – use in various industrial processes such as cooling or washing

landscaping – artificial infiltration or filling of lakes and fountains

In the future, there will be great pressure on the quality of discharged wastewater, not only from the point of view of nutrients, but also of micropollutants such as drug residues, antibiotic resistance genes, microplastics, pesticides, etc.

Around the world, the designation of a wastewater treatment plant (in English) is already changing to a water reclamation plant in a loose translation, i.e. a place where we recover water.

**1.3** *He is curious: in connection with wastewater, so-called micropollutants are often discussed. This is a broad term that includes substances such as drug residues, hormones, microplastics, pesticides, substances from personal care products, some substances used in industry. This is a broad group of substances that occur in wastewater in very low concentrations. The level of their removal at cleaning plants is different, it always depends on the specific substance. Their removal is also complicated by the fact that their concentrations in wastewater are very low. For their more effective elimination, in the future it will be necessary to supplement the technologies of the treatment plant with specialized stages, such as advanced chemical oxidation, sorption on activated carbon and the like.*

## The story of substances and energy obtained from wastewater

**Interpretation tip:** When telling this section, you need to really get the participants excited, as there is still a big stigma in society about wastewater treatment. People understand the need for wastewater treatment, but they only take it as a necessity. You can present the participants with a new perspective on this side of the matter – at treatment plants, we can obtain valuable substances when cleaning wastewater, e.g. activated sludge is considered waste, but it can also be viewed as a valuable raw material! The sludge itself has excellent fertilizing properties, it releases nutrients gradually, and it also helps the soil retain water. By further processing the sludge, we can obtain energy (e.g. by processing biogas) as well as the elements contained in the sludge - mainly phosphorus and nitrogen compounds.

Wastewater contains an incredibly large amount of different substances and energy. For example, if we look at human digestion, a large part of substances from food passes into wastewater, because our digestion is not completely perfect and we cannot fully use all substances.

**ZŠ:** *Only summarize the substances that can be obtained from wastewater and focus on the use of sludge on agricultural land or incineration.*

**Secondary school:** *Older pupils can go into more detail about anaerobic stabilization and precipitation of phosphorus.*

**Curious:** *Describe in detail the different types of combustion (pyrolysis, gasification), what are the products here and mention biochar as a perspective substance. This group also includes the topic of refining biogas into biomethane. It should be mentioned that some treatment plants in Europe (even in the Czech Republic) are already energetically self-sufficient, or even produce more energy than they consume, thanks to the sufficient production of biogas.*

? Question: What substances can we get from wastewater?

- 💡 Answer: Summary of substances that we are able to obtain from wastewater:
- Organic substances, N, P,....
- Kal
- Energy
- Other - fat, cellulose

Gravels, sand

***Inquisitive: In the past, faeces were mainly used in agriculture as fertilizer. Urine used to be used as a cleanser, the ancient Romans used urine to whiten their teeth. Fabrics were soaked in urine before dyeing to make the color more durable. Urine was also an important raw material for the production of gunpowder. Feces were used to treat leather, tanners had so-called urinals in pubs to collect urine.***

? Question: What substances are separated from water during mechanical water purification?

💡 Answer: In the mechanical part of the wastewater treatment plant, we obtain slag, sand, gravel, oils and fats from wastewater. Scraps are hygienically objectionable, for this reason they are landfilled or burned in incinerators. One inhabitant produces on average 5-15 liters of shards per year. Sand and gravel are also hygienically objectionable, but they can be used, for example, in the construction industry after treatment. Oils and fats are used in anaerobic stabilization and then biogas is produced from them, which can be used for energy.

? Question: How are nutrients removed from wastewater?

💡 Answer: Several biological processes are used to remove these elements, which take place in the activation tank of the treatment plant.

- Carbon removal

Oxidation of organic substances by the action of microorganisms in the presence of oxygen to carbon dioxide and water. Carbon dioxide is a harmless gas that escapes into the atmosphere.

- Nitrogen removal – nitrification and denitrification
- Nitrogen enters wastewater mainly from urine.
- Nitrogen is removed through two processes: nitrification and denitrification.
- During nitrification, nitrifying bacteria oxidize the ammonium ion via nitrites to nitrates. During this process, the tanks need to be intensively aerated, as a large amount of oxygen is consumed during this process. Aeration is energetically and therefore also financially demanding. Aeration takes place with the help of blowers and aeration elements, which are located at the bottom of the tank. The blower blows air into these elements. Fine bubbles subsequently emerge from the elements.
- During denitrification, nitrates are converted into nitrogen gas. In the end, nitrogen (a harmless gas that makes up about 78% of the atmosphere) disappears from our water, leaking into our atmosphere. During denitrification, organic carbon from wastewater is also consumed.
- If there is a lack of organic carbon in the wastewater, it is necessary to apply an external substrate (most often methanol) to the tanks - the bacteria then use the external substrate to metabolize nitrate into nitrogen gas.

Because of sufficient organic carbon, there is usually a tank in which denitrification takes place prior to nitrification. An internal recycle then works between the tanks, where part of the wastewater from the nitrification is pumped back into the denitrification, so that the nitrates created in the nitrification are transported to the denitrification, where the conditions are suitable for their removal. Note: this section can vary significantly depending on the specific dry cleaner. Adapt the interpretation to your technology and especially to your audience. A detailed description of nitrogen removal can be very confusing and complicated for elementary, but often also secondary schools.

- Phosphorus removal – chemical precipitation or enhanced biological phosphorus removal
- Phosphorus enters the wastewater from faeces, from industrial laundries (they are allowed to use phosphate detergents), from tablets in dishwashers.

Phosphorus can be removed from water by chemical precipitation or enhanced biological removal of phosphorus using special phosphorus-accumulating bacteria.

? Question: Are any greenhouse gases produced during the removal of nutrients?

💡 Answer: During activation, greenhouse gases are produced: carbon dioxide (a product of the removal of organic carbon), nitrous oxide (created during nitrification) and, in some places with an extremely low concentration of oxygen, methane. Nitrous oxide and methane have a significantly higher greenhouse effect than carbon dioxide. Other greenhouse gases are created during the production of electricity to drive machines at the treatment plant.

? Question: What is sludge from the point of view of sludge management?

💡 Answer: Sludge is a waste product of wastewater treatment, which represents 1-2% of the volume of treated water, but 50-80% of the original pollution contained in the inflow to the wastewater treatment plant is concentrated in it. The treatment and processing of sludge aims to minimize negative impacts on the environment and human health. We deal with sludge in different ways, which depend on the size of the treatment plant.

At the wastewater treatment plant, we collect sludge from two tanks. First, we remove sludge from the settling tank, which is called primary sludge. Subsequently, we remove sludge from the settling tank, which is called secondary or excess. The mixture of primary and secondary sludge is called raw sludge.

**ZŠ: If you and the participants move from the drain to the sludge management, it is a good idea to remind them again in a simplified way what sludge is and where it comes from.**

**SŠ: With this group of students, it is ideal to start a debate at the beginning of sludge management on what substances are found in sludge and what can happen to them, trying to get to other substances than just organic pollution. Sludge contains a mixture of organic and inorganic substances, water and various toxic substances such as heavy metals, pesticides, drug residues or pathogenic and other microorganisms.**

**Curious: The cost of acceptable sludge treatment corresponds to approximately 50% of the operating costs of wastewater treatment. It is not worthwhile to have sludge management at smaller treatment plants.**

? Question: How is sludge processed at small treatment plants?

💡 Answer: Anaerobic stabilization does not occur at small treatment plants due to insufficient production of biogas. This means that the sludge is usually either aerobically stabilized or dewatered, or liquid transported to a larger treatment plant. During aerobic stabilization, the sludge is either left for a longer time in the activation tank, or is pumped into an aerated sludge sump. After dewatering, the sludge can be transported to a larger treatment plant, where it is subsequently transferred to digester tanks.

? Question: How is sludge processed at larger treatment plants that have sludge management?

💡 Answer: At medium and large treatment plants, anaerobic sludge stabilization (or anaerobic digestion) is most often used. A large amount of the original pollution contained in the inflowing wastewater is concentrated in the sludge. At larger treatment plants, part of this pollution is converted into biogas in digestion tanks (through anaerobic stabilization).

During anaerobic stabilization, sludge is collected in tanks in which access to oxygen is restricted (=anaerobic environment). In these tanks, the substances contained in the sludge are decomposed with the help of special bacteria (methanogenic bacteria) to produce biogas. According to the temperature in the tanks, we distinguish between mesophilic (35 °C) and thermophilic digestion (55 °C).

After the sludge passes through the digestion tank, it becomes stabilized sludge, which means that intensive spontaneous decomposition should no longer take place in it. In anaerobic digestion, approximately half of the dry matter of the sludge is converted into biogas.

**SŠ:** *The digestion process is also referred to as anaerobic stabilization. The bacteria contained in the sludge gradually metabolize organic substances into simple sugars and alcohols and subsequently into carbon dioxide, hydrogen and methane. The mixture of gases produced in this process is called biogas and consists mainly of carbon dioxide and methane (approx. 60-80%). A device in which biogas is converted into heat and electricity is called a cogeneration unit. Biogas is used to drive an internal combustion engine or turbine. Burning biogas produces heat and at the same time powers a generator that produces electricity.*

**Inquisitive:** *In addition to carbon dioxide and methane, anaerobic stabilization also produces ammonia (ammonia) and sulfane, which are strongly smelling gases.*

**Curious:** *Methanogenic bacteria are a very old group of bacteria in terms of development, they appeared 3.5 billion years ago (the age of the Earth is 4.5 billion years). At that time, there was no oxygen in the atmosphere, and Earth's atmosphere resembled that of Venus today. In comparison, dinosaurs appeared 250 million years ago and man 2.8 million years ago. If the axis were 0 the creation of the Earth and 10 the present, then methanogens appeared at point 2.22, dinosaurs at 9.44 and man at 9.99).*

? **Question:** What is the use of stabilized sludge?

💡 Answer: The use of stabilized sludge depends on its quality. This sludge can be applied to agricultural land thanks to its fertilizing properties, as it contains a large amount of organic matter, phosphorus and nitrogen. It can also be used in composting plants. Another method of processing is thermal processing, which includes combustion, pyrolysis or gasification. During pyrolysis, pyrolysis gas (syngas), oil and solid residue (biochar) are formed. Nowadays, biochar appears to be a very promising substance that, for example, increases water retention in the soil.

The issue of applying stabilized sludge to agricultural land is complex because, on the one hand, we know that sludge is a valuable fertilizer, but on the other hand, it can be a source of a number of pollutants, such as heavy metals, drug residues, pathogenic microorganisms (e.g. Salmonella) and persistent organic substances. Therefore, sludge applied to agricultural land must certainly comply with legislative regulations. Legislative regulations monitor not only the quality of sludge,

but also in what quantity and where sludge can be applied. Technically, it is necessary to have contracted farmers who have sufficient capacity to store the sludge, because the soil is fertilized a few times a year, but the production of sludge is continuous.

**SŠ:** *If you and the students had a debate about what substances sludge contains, you can try to follow up with a question about them. What do they think - where does the cleaning sludge go and where could it be further used? Stabilized sludge is used in agriculture due to the use of the fertilizing properties of the inorganic and organic nutrients contained in it. Are there any risks to using sludge in the field? (simplified only)*

**Curious:** *A possible risk of applying stabilized sludge to agricultural land is the content of micropollutants in the sludge. Among the micropollutants that sludge contains are microplastics, pesticides, endocrine disruptors and drug residues. Despite their low concentration, these substances can potentially have negative effects on the environment and human health. The legislative parameters for the use of sludge on agricultural land include microbiological criteria (Salmonella, E. coli and enterococci) and limits on the content of heavy metals, polychlorinated biphenyls and polycyclic aromatic substances.*

*Antibiotic resistance genes can also be found in the sludge, which can then spread to other bacteria.*

*The technologies that can be used to treat sludge also include pyrolysis or gasification, where fuel is produced from sludge. E.g. in neighboring Germany, the most common way of dealing with sludge is to incinerate it. Sludge is either incinerated separately in a specialized incinerator, or mixed with other material and incinerated together, e.g. in a waste incinerator, power plant/heating plant or cement kiln.*

*A large amount of phosphorus is stored in the sludge, which can be obtained from the sludge thermally (recovery of phosphorus from ash after burning the sludge) or chemically (precipitation).*

? **Question:** How is the resulting biogas utilized?

💡 **Answer:** Biogas is burned in a cogeneration unit, which produces heat and electricity from it. The heat is used back to heat the digester tanks. The generated electricity is used at the treatment plant, e.g. for running pumps or aerating the activation tank.

Another possibility of using biogas is its refining into biomethane. Biomethane has qualities similar to natural gas and can be pumped into the gas pipeline network.

## The story of people taking care of the sewer network and working at the wastewater treatment plant

**Interpretation tip: Most people have no idea how difficult it is to remove and treat sewage and how many people in different positions are involved in this process. For this reason, we recommend enriching the excursion with a mention of the people who work in the sewage system or at the treatment plant at suitable places. By increasing knowledge about these positions, it is possible to increase the level of perception of the importance of these occupations and also the interest to study them. Here it is possible to mention how the need for these professions will develop and also how, for example, the work content of individual employees will change (e.g. carbon footprint calculation, digital twin of wastewater treatment plants or ESG reporting).**

Wastewater removal and treatment is a continuous process that cannot simply be stopped. So that everything works and the whole process does not stop, it costs a lot of effort and work of many people of different professions. Individual professions follow each other and one cannot function without the other. We can see the sewer network and the wastewater treatment plant as one well-oiled machine.

The sewer system needs to be checked regularly and in the event of malfunctions or clogging with dirt, it must be repaired or cleaned. The survey of the sewer network is carried out by a water management technician specializing in network diagnostics using a camera system that is placed at the beginning of the inspected location and the cameras are guided through the pipeline using a remote control. In case of detection of impaired pipe permeability, cleaning with a nozzle and pumping out the material using a high-pressure cleaning truck is used. Recently, there are even drones that automatically fly through the sewer and take the necessary measurements. Repairs and cleaning are carried out by operating fitters and operators of a special sewer cleaning truck.

A number of devices are in operation at the wastewater treatment plant, the operation of which is directly managed by water management equipment engineers. These workers ensure the operation of machines and technological equipment and ensure their full functionality and regular inspection. Maintenance and repairs of electrical equipment are carried out by operating electricians. The operation of the wastewater treatment plant is continuous, which is why it is necessary to have constant supervision over the processes at the treatment plant, which is ensured by dispatchers (controllers). Dispatchers watch the outputs from the operation on the monitors and use the control system to control the operation of the wastewater treatment plant. Dispatchers work in shifts so that 24/7 supervision of the treatment plant is ensured.

The quality of wastewater and various outputs of the wastewater treatment process is monitored through the laboratory. Laboratory staff process samples and carry out chemical, microbiological and hydrobiological analyses. Samples are collected and transported to the laboratory by samplers.

The technologist is responsible for the proper functioning of the wastewater treatment plant and the quality of the treated wastewater flowing out. Based on the results of analyzes from the laboratory, values from probes, analyzers and flow meters at the treatment plant, it evaluates the cleaning process and adjusts the settings of individual devices to ensure smooth operation and good quality of the flowing water.

The control system is checked and developed by IT experts. An interesting sector is also the creation of so-called digital twins of wastewater treatment plants using specialized software, which find use, for example, in testing various unusual situations or optimizing operations.

Recently, there has been an increasing interest in monitoring the carbon footprint and other parameters related to the impact of equipment on the environment, and with it the need for these experts in the water management field.

From the list of professions mentioned above, it can be seen that both a worker with a training certificate and a university degree can find employment at a wastewater treatment plant.

*Elementary school: Just summarize the professions and try to list them for the tanks and machines where their work is performed, so that they have as much idea of the given profession as possible.*

*Secondary school: For older pupils, there are options where you can study for the position of water technologist - universities with a focus on water (VŠCHT, BUT, VŠB).*

*Inquisitors: Here, it is up to you whether to bring various objects with which these professions work: sample boxes, instruments, measuring cylinder for sludge index, camera, etc.*

## Water pricing

The price of water is a frequent topic in the media and public discussions, but few people really know how the total price of water is calculated and how much effort it actually costs to produce drinking water and treat wastewater. Often people imagine that drinking water can be taken straight from the source, which is free, and then discussions arise about the fact that water management companies make huge money from what is actually free in nature. It is not so! And that is why it is important to familiarize children with how the price of water is created, what it consists of, and how financially demanding the processes of producing drinking water and cleaning wastewater are.

The total price of water consists of two items, which are called water and sewage. Water fee is a fee for the production of drinking water and its delivery to our home (to the consumer). Sewage is a fee for removing wastewater from its source (e.g. from a household) and its subsequent treatment.

The price of water is regulated, i.e. created according to the rules established by the Ministry of Finance of the Czech Republic. These rules define what items the final price can and cannot consist of and what profit the water companies can keep. The price of water is updated every year. The owner of the water management infrastructure has the final say in the creation of the price.

- **Water price = authorized costs + reasonable profit + state levies**
  - o eligible costs (examples):
    - o acquisition/rental, restoration and modernization of water management property
    - o consumption of electricity, chemicals, water quality control (laboratory work), etc.
    - o maintenance and repair costs
- wages of employees ensuring operations, customer service (contracting, invoicing, complaints)
  - o reasonable profit
  - o regulated by the Ministry of Finance of the Czech Republic
- max. 7% of the invested capital
  - o state levies
  - o VAT
  - o wastewater discharge fees

fees for taking raw water from which drinking water is subsequently produced

**ZŠ:** Just explain the concepts of water and sewage. And compare the price of one liter of tap water compared to other prices, e.g. bottled water, Coca Cola, sweets, etc. For a better idea of how much 1m<sup>3</sup> of water is, it is good to say that it is the same as 500 two-liter bottles.

**SŠ:** Compare the price of water with other expenses – for example, with the price of electricity, Netflix, monthly phone bill, etc.

**Inquisitive:** To describe in more detail what the price of water consists of - the individual items that are included there.

? **Question:** What was the average price of water in the Czech Republic in 2024?

💡 **Answer:** In 2024, the average price of water (sewage + water) was CZK 125 per m<sup>3</sup>. The average price of water was 63 CZK per m<sup>3</sup> and the average price of sewage was 59 CZK per m<sup>3</sup>.

For a better idea, we also present a conversion to the price for one liter of water. The average total price of water was 0.125 CZK per liter, of which the average price of water was 0.063 CZK per liter and the average price of sewage was 0.059 CZK per liter.

? **Question: Is tap water expensive?**

💡 **Answer:** The best answer to this question is to compare one person's water consumption with his other expenses and the price of water and sewage in the given area. For example, we present a comparison with the average price of water in the Czech Republic from 2024.

The average consumption of tap water per person in the Czech Republic is about 90 liters per day.

Price list: Period	Number of liters of wastewater (1 person)	Price of drinking water	Price for water purification	Total price
1 day	90 l	CZK 5.67	CZK 5.31	CZK 10.98
1 month	2 700 l	170.1 CZK	CZK 159.3	329.4 CZK
1 year	32 850 l	CZK 2,069.55	CZK 1,938.15	CZK 4,007.7

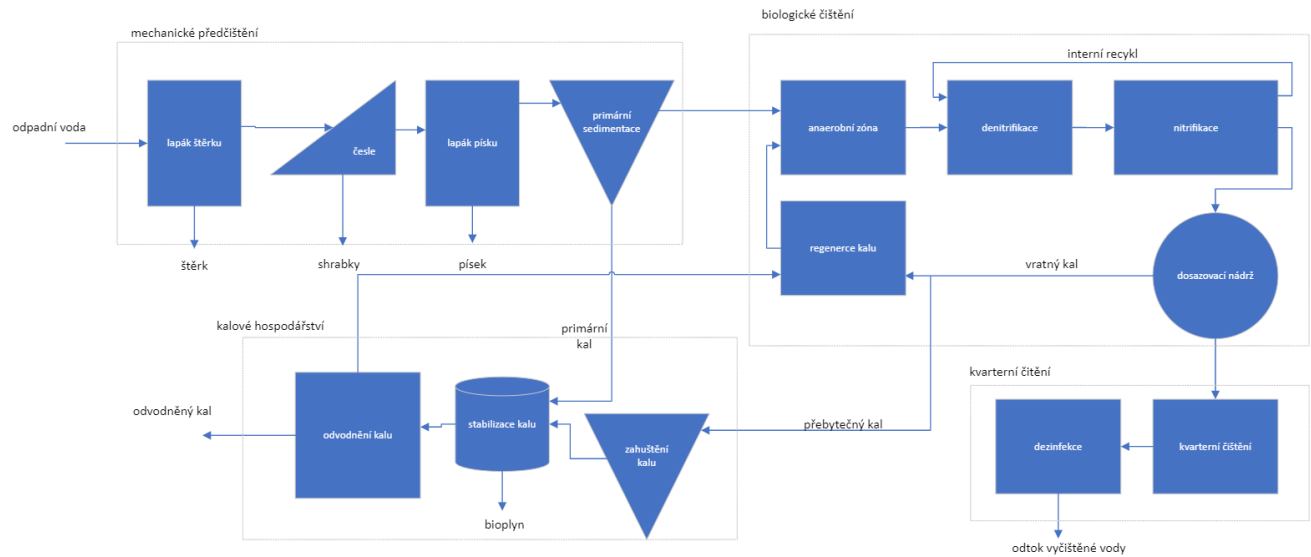
Period	Number of liters of wastewater (4 people)	Price for water purification
1 day	360 l	21.24 CZK
1 month	10 800 l	637.2 CZK
1 year	131 400 l	7,752.6 CZK

? **Question:** Will the price of water be lower if we all start saving water?

💡 **Answer:** No, the decrease in water consumption leads to an increase in the price per liter, because a large part of the costs in the water industry are fixed. For example, it doesn't matter if less or more water flows through an existing pipeline, its maintenance, repair and service will still be needed.

## Description of WWTP technologies


**Interpretation tip:** In this chapter you will find basic information about technologies, facts and interesting facts. Use this chapter as a catalog from which you can choose information about the technologies you have at your cleaning plant.




## Mechanical cleaning

First of all, the WWTP needs to remove undissolved material that could clog pumps, settle in tanks or destroy other equipment (abrasion).

### Gravel trap

	<b>Importance</b>	Capture of large objects that are able to settle to the bottom (sediment).
	<b>Principle</b>	A sump in which the flow of wastewater slows down and thus sediments the material. The captured material must then be dredged from the bottom and loaded into a container that is taken away from the wastewater treatment plant, usually to a landfill.
	<b>Captured material</b>	Gravel, stones.

### Chisel


	<b>Importance</b>	Removal of larger floating debris.
	<b>Principle</b>	A sieve-like device through which water is filtered. The material that gets caught on this net is called rakes. The captured material is then removed from the combs (manually or automatically) and loaded into a container, in which it is usually taken to a landfill.
	<b>Captured material</b>	<b>= rakes</b> branches, rags, packaging, leftover food, fruit and vegetables, condoms, pads, tampons, wet wipes... wallet, documents dead rats, money, jewelry, clothes, keys, pillows, banana peels

**ZŠ:** Here it is appropriate to draw attention to what does not belong in the sewage system and explain why. Usually some of this will float up and the problem can be pointed out directly.

**Inquisitive:** Scraps are usually the most hygienic material that can be encountered at a dry cleaner. At the same time, it is a material that should not enter the sewage system at all.

**Interpretation tip:** It is possible to prepare a small "exhibition" of interesting exhibits on combs or perhaps show photos of interesting things captured on combs.

## Sand trap

	<b>Importance</b>	Separation of sand (inorganic material) from organic suspended matter, which is important in the next part of the wastewater treatment plant technology.
	<b>Principle</b>	Separation of sand from organic suspended substances takes place on the basis of their different densities. Sand traps differ in whether gravity or centrifugal force is used for separation.
	<b>Captured material</b>	<b>= sand</b> heavy inorganic substances – sand, glass fragments, fine slag

? Question: Why is the sand trap aerated when the sand is supposed to settle here?

💡 Answer: It is due to the separation of organic impurities from the sand. We only need to remove the sand in the sand trap. Organic substances would cause rotting of the trap and the excavated sand, moreover, we need them as food for bacteria further in the process.

## Settling tanks

	<b>Importance</b>	Sedimentation of undissolved substances of organic origin and wiping of floating impurities from the surface.
	<b>Principle</b>	The sedimentation tank works on the principle of gravity, when heavier particles sink to the bottom and are subsequently sucked from the bottom for further processing.



**Captured material**

= primary cal  
 The material settled at the bottom of settling tanks is referred to as primary sludge. This sludge is rich in organic substances and is used in sludge management.

*Inquisitive: Sedimentation tanks can remove roughly 30% of incoming pollution, and at the same time, the sludge captured here contributes roughly half to the total production of biogas and electricity.*

**Biological cleaning  
 Activation tank**



**Importance**

Biological removal of carbon, nitrogen and phosphorus - collectively called nutrients.

**Principle**

Countless biological processes take place here. The pollution contained in the wastewater is metabolized by bacteria in specific conditions, which are adjusted so that selected bacterial strains survive (and prevail) in the tanks. The group of bacteria and microorganisms that metabolize pollution in wastewater is called activated sludge. As the microorganisms consume the pollution, they grow and multiply. It follows that the amount of activated sludge increases over time and the excess sludge must be regularly removed from the activation tank.

**Captured material**

No material is directly captured here, but there is growth and reproduction of activated sludge bacteria on which various types of substances can be sorbed (captured). Bacteria further transform organic substances, nitrogen and phosphorus into forms that are removed from the water.

? **Question: Can you swim in activation tanks?**

💡 Answer: You cannot swim in tanks, the mixture is so strongly aerated that it has too low a density for swimming. If someone tried to do that, they would drown. Tanks therefore need to be secured against workers falling, or use securing on ropes, etc.

? **Question: Are the conditions different in the tanks?**

💡 Answer: The conditions in individual reservoirs differ significantly.

nitrification – high oxygen concentration (aerobic zone)

denitrification – without oxygen, but with nitrates (anoxic zone)

phosphorus removal – without access to oxygen and without nitrates (anaerobic zone)

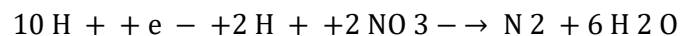
*some treatment plants do not have separate tanks set aside for different conditions, but the conditions are changed over time in one tank*

**ZŠ:** *For these pupils, it is necessary to ensure that the process is as clear as possible. It would be useful to have ready pictures of the microorganisms that are contained in the activated sludge, but there is no need to mention the names. You can also show them what the aeration element looks like (physically, a picture, a photo of the drained tank).*

*We can show that sludge consists of individual flakes that can be seen with the naked eye. Furthermore, to say that these flakes are formed by microorganisms that feed on pollution.*

**SŠ:** *Here it is possible to talk in more detail about the individual biological processes of nutrient removal, to have prepared nitrification and denitrification reactions, to directly mention the organisms that are responsible for these processes. Mention that in activated sludge, in addition to bacteria, there are also protozoa (filiforms, molluscs, cryptids), metazoa (rotifers, nematodes, worms) and, to a lesser extent, molds, fungi and yeasts.*

Denitrification:



Nitrification (consists of two reactions):

nitritation – oxidation of ammonia nitrogen to nitrite nitrogen




nitration – oxidation of nitrite nitrogen to nitrate nitrogen



**Inquisitive:** *At some treatment plants, the activated sludge is regularly examined under a microscope to check which bacteria and microorganisms are contained in the sludge and*

*with what frequency. The functioning of individual processes can be assessed from certain species and the overall composition of organisms.*

## Settling tank

	<b>Importance</b>	The tank serves to separate the activated sludge from the purified wastewater.
	<b>Principle</b>	<p>The water flow in the tank will slow down. Activated sludge can settle to the bottom of the tank under these conditions. From the bottom of the tank, most of the activated sludge is returned to the activation tank, where the sludge cleans the water again. Since activated sludge is a living organism that multiplies, it is necessary to maintain only the necessary amount in the system and to pump away its excess from the system. Excess sludge that is not used back in the activation tank is pumped to the sludge management. At treatment plants without sludge management into a storage tank. From where it is then taken to larger treatment plants with sludge management.</p> <p>Above the settled sludge is purified wastewater, which overflows from the tank into the drain and then continues to the recipient (river, stream,...).</p>
	<b>Captured material</b>	<p><b>Excess sludge – excess activated sludge that is removed from the system.</b></p> <p><b>Return sludge - activated sludge that returns to the activation tank and cleans the wastewater again.</b></p>

***Inquisitive: In the case of settling or activation tanks, it is possible to explain to the participants how the quality of the sludge is determined from the point of view of settling, i.e. the sludge index. The sludge index is measured using a sedimentation test, when a sample is taken from the tank and poured into a measuring cylinder, then after 30 minutes the height of the interface between water and sludge is measured. The silt index is then calculated as the sediment height divided by the sedimentation time. According to the calculated sludge index, it is possible to assess how easy or difficult the sludge settles.***

**Interpretation tip: We can perform the sedimentation test on site. At the beginning of the interpretation at the activation tanks, take a sludge sample, and at the end of the interpretation, the water-sludge interface and offset water could already be seen. If we are going to do this demonstration, it is advisable to collect the inflowing wastewater in this way and show the difference in the appearance of wastewater and purified water.**

### Tertiary cleaning Water disinfection



**Importance**

Cleaned wastewater still contains various bacteria, viruses and parasites that can have a negative effect on aquatic ecosystems. Disinfection reduces the number of microorganisms and ensures environmental protection.

**Principle**

It is possible to use several methods, e.g. UV radiation or ozonation. UV radiation of a given wavelength penetrates a narrow layer of water. This radiation subsequently kills microorganisms (only kills, not removes). Another method is the application of a disinfectant, for example hydrogen peroxide.

### Filtration through a layer of activated carbon




**Importance**

With stricter limits for substances other than nutrients, it is possible to apply filtration through a layer of activated carbon. Activated carbon is able to remove micropollutants (substances contained in water in very low concentrations).


**Principle**


Adsorption of organic substances, drugs, heavy metals and other impurities from wastewater onto activated carbon


## Membrane technology

	<b>Importance</b>	We approach the use of membrane technologies when we want to have extremely high-quality water at the outlet. When membrane technology is used, the number of bacteria, the concentration of elements and compounds is reduced, depending on the size of the pores of the membrane.
	<b>Principle</b>	Cleaned wastewater is pumped through the membrane, which is made up of holes of a given size (we differentiate: microfiltration, nanofiltration and ultrafiltration). Water and substances that are smaller in size than the given holes will flow through the membrane, while substances larger than these pores will begin to accumulate on the membrane.

## Chemical precipitation of phosphorus on the drain

	<b>Importance</b>	If the concentration of phosphorus in the effluent from settling tanks is still high and does not meet the limits, it is possible to reduce the concentration of phosphorus by chemical precipitation.
	<b>Principle</b>	Residual phosphorus contained in the purified water is precipitated using a precipitating agent. Treatment plants apply various substances, most often sulfate or ferric chloride. The iron salt reacts with phosphates to form an insoluble ferric phosphate compound.

<b>Sludge management</b> <b>Sludge thickening</b>		
	<b>Importance</b>	Reduction of water content in sludge before further processing.
	<b>Principle</b>	Sludge is thickened by gravity in thickening tanks or mechanically in a thickening centrifuge or thickening screen.

Sludge stabilization		
	<b>Importance</b>	Production of stable and safe material that can be further used, for example, in agriculture.
	<b>Principle</b>	<p>Sludge stabilization leads to a decrease in the amount of organic substances in the sludge and to a reduction in the number of pathogenic and other living organisms. Stabilized sludge does not decompose further and does not cause odor problems.</p> <p><u>Types of sludge stabilization:</u>            anaerobic            aerobic            chemical</p> <p>During anaerobic stabilization (putrefaction) of sludge, organic substances are converted into biogas, which is further processed for energy. It is used in medium and large treatment plants.</p> <p><b>Aerobic stabilization is based on sludge aeration. The organic substances contained in it are oxidized.</b></p> <p>During chemical stabilization, quicklime (CaO) is added to the sludge. The quicklime reacts with the water present in the sludge to produce heat and hydroxide, which will increase the pH and thereby inhibit the activity of microorganisms.</p>

## Sludge dewatering



### Importance

Reducing the water content in the stabilized sludge, so that it can be used further and the costs of its transport are reduced (a lower amount of water means a smaller volume of sludge, which means a smaller number of filled containers).

### Principle

Sludge is dewatered mechanically or on sludge fields.

Machine methods include:

- centrifuges
- sieve belt presses
- calopresses
- vacuum presses
- screw press

**The centrifuge works on the principle of centrifugal force. This is such an accelerated settling of particles (sedimentation). During centrifugation, the centrifuge rotor rotates rapidly and the sludge is separated into solid particles and water. Kalolisy are then such a sieve that captures sludge and lets water through.**