VODOHOSPODÁŘSKÉ TECHNICKO-EKONOMICKÉ INFORMACE
(WATER MANAGEMENT TECHNICAL AND ECONOMIC INFORMATION)

VTEI/2023/6

60 years ago in VTEI

At the end of the 1950s, the VTEI journal published an article by Josef Beneš from the Ministry of Agriculture, Forestry, and Water Management entitled "Water purity in new regulations".

The critical condition of the purity of watercourses is widely known in our country, and 3,200 km of watercourses being polluted to IV and the V class of purity speaks very clearly in comparison with the 8,000 km total length of the most important watercourses. However, the situation is not yet improving and, given current industrial development, we can count on some improvement at the end of the third five-year plan at the earliest.

The overall direction in dealing with water purity is based on legal regulations and valid government regulations. However, it is necessary to take into account the relatively slowly changing opinion on the necessity for better water management at many plants.

An amendment to the Water Management Act of 1959 brought certain changes in order to improve water purity. For example, Section 12 clearly formulates the obligation of water users to systematically remove existing water pollution not only by building wastewater treatment plants and their proper operation, but also by implementing the necessary measures in production technology, where disposal of wastewater is often more advantageous than in a treatment plant. There is a great scope for innovators and inventors. It is only necessary for the plants to properly direct their efforts. The same paragraph also talks about the possibility of imposing property sanctions on polluters for violating their obligations arising from the law. More detailed guidelines are contained in Government Regulation No. 603/58 and 385/60.

Section 24, which deals with investment activities, describes the water management negotiation procedure, including a list of data necessary to assess investments from a water management point of view. The novelty is that in the preparation phase of the investment task, the water authority has the right and obligation to decide on the possible further use of investments. For treatment plants, this means, for example, prescribing certain measures in order that the wastewater of two or more plants, housing estates, a town, etc. is disposed of in one treatment plant. Such options must be carefully considered and tested. Fundamentally, however, the joining of treatment plants must not delay the removal of serious sources of pollution.

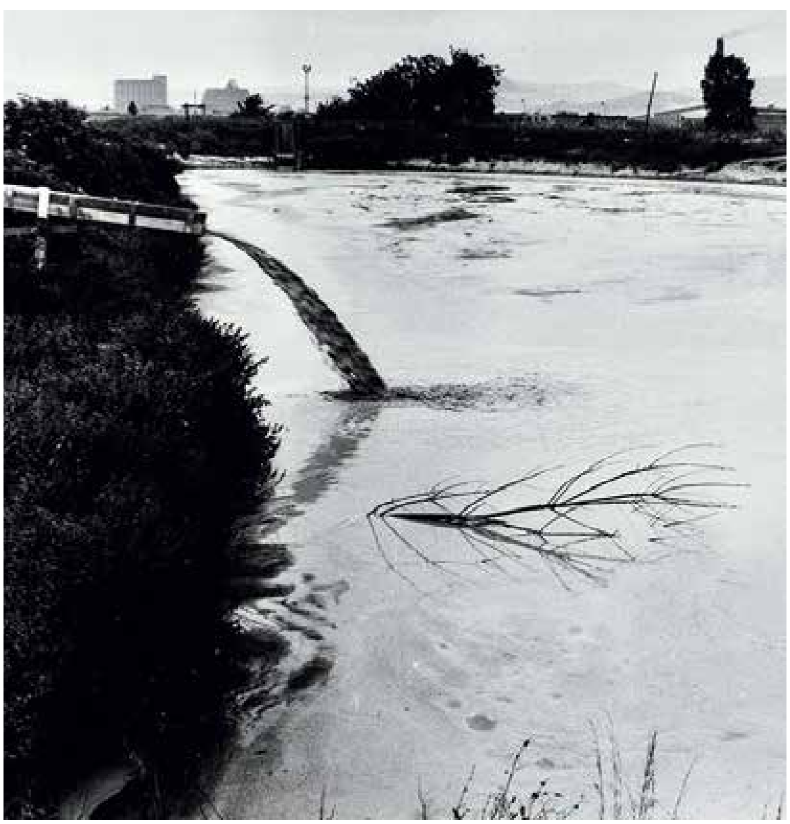
The law also gives the possibility of imposing fees for the discharge of wastewater according to the degree of pollution. This option has not been used yet, but current developments show that this measure will be necessary.

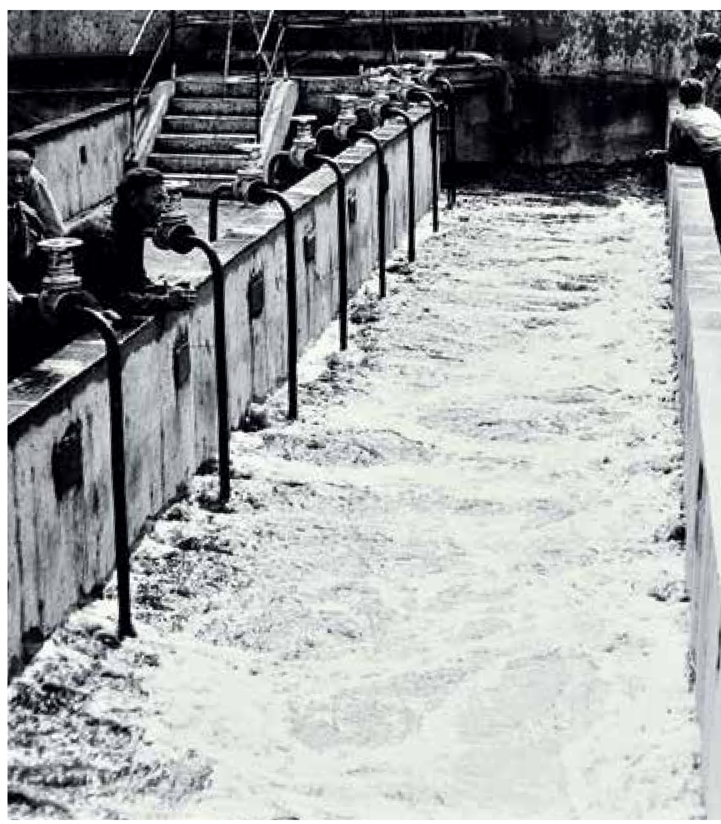
A new measure to help improve water purity is consistent monitoring. The bodies of the State Water Management Inspection of the Ministry of Agriculture, Forestry, and Water Management and in the regions are facing big challenges. They can provide expert advice at plants, help water authorities monitor polluters, and ensure that deficiencies are rectified and negligence punished.

We have a big task ahead of us – the third five-year plan. Specific tasks in the area of water purity were outlined by Government Regulation No. 385/60, which points out 678 sources of pollution to be eliminated in 1961–1965. It is a huge task, and it is clear that fulfilling it will be met with great difficulties. Just as decisions are already being made today on the fulfilment of the third five-year plan, decisions are also being made on the possibility of raising the standard of living by further expanding industrial and agricultural production. Only through the joint efforts of all employees of water management bodies and organizations, all designers, builders, engineers, investors, operators, and all workers of our Republic will we be able to fulfil the direction given by the law on the third five-year plan: to achieve a fundamental turnaround in the purity of watercourses.

From TGM WRI archives

VTEI Editorial office





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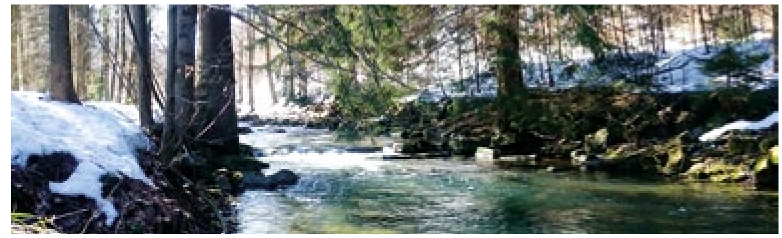

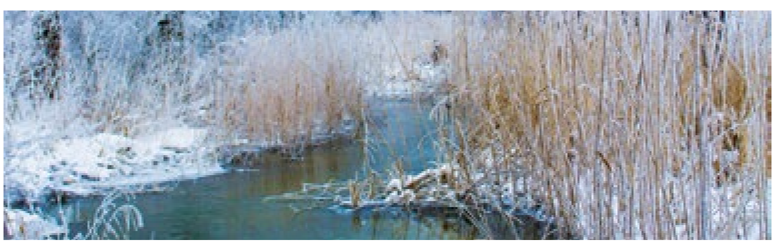


PF 2024
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Dear readers,

As the end of 2023 approaches, we are pleased to present to you the last issue of this year's VTEI journal. Although it does not have a common theme like the October issue, most of the articles coincidentally have a common theme, which is wastewater, or waste in general.

The first of them is an article about the promising possibilities of wastewater treatment from specific organic contaminants (EC) by the action of an electrostatic field emitted by modified laboratory equipment for the physical treatment of waste. The first series of experiments was aimed at eliminating the much-discussed metabolites of selected pharmaceuticals.

No less beneficial and interesting is another article about the results of a pilot project regarding the detection of drug use in primary and secondary schools through the analysis of wastewater. Although the established procedures have so far only been applied at four selected schools, they showed that (taking into account the specific circumstances of the operation of individual schools and the circumstances of sampling), it is possible to detect quite reliably the use of both illegal drugs (marijuana, methamphetamine, amphetamine, cocaine, ecstasy) as well as nicotine.

The topic of waste is also discussed in an article that, as part of the presentation of the interim results of the project *"Centre of Environmental Research: Waste management, circular economy and environmental security (CEVOOH)"*, provides a brief outline of the procedures and legislative measures applied in the collection and management of biodegradable municipal waste in selected countries of the European Union as well as general conclusions, which will be appropriate to implement in the Czech Republic based on good practice.

A topic other than waste and wastewater is covered by an article about the development of land use in groundwater zone 4232 ''Ústecká syncline'' and the effect of this use on water resources. It primarily emphasizes the need to carefully monitor changes in the landscape and the future development of this area (whose water resources are among the highest quality and most abundant in the Czech Republic) and to actively support changes to the landscape with an expected positive impact, for example, increasing the retention capacity of the landscape by building smaller reservoirs, wetlands, and forest stands.

In the fifth expert article, the authors deal with the state of surface water at selected 11 locations in three basins. Current monitoring of priority substances and specific pollutants is not able to capture all sources of pollution, and it also does not allow for a comprehensive assessment of mixtures, metabolites, or other substances. Therefore, the article "Use of effect-based methods to assess surface water status" provides a view of the application of this method with the possibility of evaluating the overall biological effect of substances on water quality.

For the current issue, we had the honour to interview Prof. Pavel Pech, a notable pedagogue from the Czech University of Life Sciences in Prague. In the interview, Prof. Pech shares his expertise and knowledge in the field of water management and offers valuable insights into the current challenges regarding climate change and the necessary measures associated with it, including the need to build new water reservoirs in our country.

The informative part talks about the "National Dialogue on Water" conference with the subtext "Comprehensive approach to the protection of drinking water sources". There was a lively discussion of participants representing the state administration, local government, but also the private sector, and thus often very different views on how to deal with the current pollution of water environment by foreign substances. How many of these substances and in what concentrations are they found in the individual phases in water? Should we be afraid of them? Can we do something about it and at what cost? Or are the concentrations so low that they are harmless to consumers' health? And what about the legislation? You can read about the conference results in the article "Looking back at the National Dialogue on Water 2023".

The informative section also presents Kozmice bird meadows, the largest private nature reserve in the Czech Republic, covering an area of 70 ha. It is located in the floodplain of the Opava river in the area between the villages of Dolní Benešov, Kozmice, and Jilešovice; its significant retention capacity is a benefit not only for the water regime, but also for the local habitats.

We hope that the December issue of VTEI will provide you with valuable insights and inspiration, and we thank all its authors and reviewers.

We wish you a pleasant time spent not only while reading VTEI; have a lovely Christmas and a successful 2024!

VTEI Editorial Office

Possibilities of wastewater treatment using an experimental device for physical action by an electrostatic field with a focus on pharmaceuticals

TOMÁŠ SEZIMA, RADMILA KUČEROVÁ

Keywords: environment — wastewater — wastewater treatment — physical action — electrostatic field — reducing the content of harmful substances — biotechnology — pharmaceuticals

ABSTRACT

As a result of climate change and the world´s population growth, ensuring sufficient amount of water is expected to be an increasing problem. There is a growing need for eco-technologies with reduced water consumption, for the use of harvested rainwater, as well as reuse of wastewater.

Currently there are millions of known chemicals, and more and more are being synthesized every day. The chemization of various branches of industry leads to the increasing massive contamination of our environment with foreign substances.

This paper presents the possibilities of rebuilding experimental laboratory equipment for the physical processing of waste into an equipment able to apply electrostatic field action on wastewater. It also considers the possibilities and perspectives of its further use, either alone or in combination with other technological processes, e.g. biotechnologies. The first series of experimental trials was aimed at eliminating selected pharmaceuticals.

INTRODUCTION

Classic mechanical-biological wastewater treatment plants (WTP) work well in most cases for basic pollution indicators (BOD_5, COD_{Cr}, $N\text{-}NH_4^+$, N_{total}, P_{total}, NL); however, they are not efficient enough to remove specific organic contaminants, the so-called emerging contaminants (ECs). In the literature, this term refers to substances that are not or have not been sufficiently controlled by existing regulations. These substances pose a significant risk to the environment and to human health, and are also one of the reasons for limiting the reusability of treated wastewater. ECs also include pharmaceuticals and other personal care products (PPCPs). The removal or significant reduction of these substances in the effluent from a WWTP could be solved by an integration of another suitable type of treatment, mostly referred to in the literature as tertiary or quaternary treatment [1]. The use of advanced oxidation processes (AOPs), ozonation, adsorption, or a combination of these appears to be appropriate and promising. Technological treatment process must be well managed otherwise, in the case of incomplete, insufficient decomposition of organic micropollutants, new products might be created which often show significantly more toxic properties than the original substances [2, 3]. Besides efficiency of this process, also today´s economic factors play a significant role, such as the price of the technology itself, its operation, energy consumption, and shelf life.

Another possible method of tertiary treatment presented here is electrostatic field application performed either alone or in combination with other technologies, for example biotechnologies.

First information on the effect of various force fields (especially electromagnetic) on humans and the environment had already been published around 1960. Currently this option is explored by several institutions, either focused on the fields themselves or in combination with other technologies; some important publications see below in the references [4–9]. A new, original device called CaviPlasma, which combines hydrodynamic cavitation and plasma discharge, looks very promising. It resulted from collaboration of the University of Technology in Brno, Masaryk University, and the Institute of Botany of the Czech Academy of Sciences, p. r. i.

Between 2007 and 2011, within the framework of the MoE R&D project SP/2f2/98/07 *"Research in utilization of waste as a substitution of primary raw materials"*, the staff of TGM WRI Prague was developing the equipment for processing waste using physical processes. Its concept was registered as a utility model under registration number: Int. 21084, Industrial Property Office on 2nd July 2010 [10]. European patent EP 2388068 [11] was granted for the equipment and method of physical treatment of waste on 22nd August 2014. Equipment for the physical treatment of materials (especially solid waste matrices) conceptually consists of the individual or selected combined action of selected force fields (microwave field, ultrasound, UV radiation, spark discharge, electrostatic field, and others, if appropriate).

Technical Description of the Original Equipment

The designed device for physical treatment of waste has been assembled from individual generators of physical force fields placed in a transparent box with a woven grounded Faraday cage with an opening inlet – handling hole. A base made of non-conductive material is loosely placed at the bottom of the box, and a plastic container (vessel) for inserting the monitored matrix for sample exposure lies on the base. The bottom of the container is formed by thick layer of plastic with a very high ohmic resistance. An electrically conductive metal mesh is loosely placed on the bottom of the container during exposure to an electrostatic field. Above the vessel, there is a second metal mesh either dipped in the sample or freely suspended above the sample. Both meshes are connected by conducting wire to an electrostatic generator. The carrier bridge with a movement mechanism carries the UV generator and the spark discharge generator. The movement of the bridge is enabled by an electric drive that can change between two speeds of movement and between two directions (back and forth). When reaching the end of the defined driving lane, the direction of movement is automatically reversed using end-of-lane switches. Driving length is mechanically adjustable. Exposure by an electric spark discharge is done by a spark gap, which is also located on the carrier bridge. Force field generators can work simultaneously, in different combinations of sequences, or independently. Currently, it is not possible to enable the joint action of the force electrostatic field and the electrical spark discharge due to the risk of damage to the electronics by the spark discharge. Device diagram see *Fig. 1*.

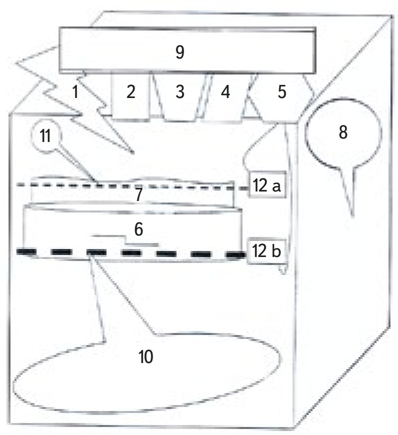

Fig. 1. Diagram of device for physical waste pre-treatment

1, 2, 3, 4, 5 – force field generators (spark discharge, microwave field, ultrasound, UV radiation, electrostatic field), 6 – plastic vessel (container for a sample), 7 – sample investigated, 8 – Faraday cage, 9 – carrier bridge, 10, 11 – conductive metal mesh, 12a, b – HV supply cables

For experimental wastewater treatment activities, optimized equipment is used for physical waste treatment with a redesigned workspace for electrostatic field action. The reaction space is currently being refined. An experimental device for water purification using an electrostatic field see *Fig. 2*.

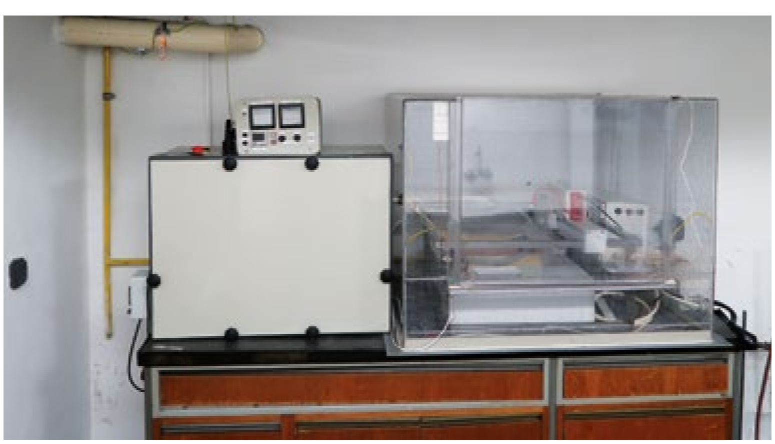

Fig. 2. Optimised testing/experimental equipment

Acting on wastewater using the above-described device with an electrostatic field may be suitably combined with other chemical or biochemical technologies and procedures. Biotechnologies seem to be feasible where physical procedures are used for initiation – opening and making matrices available for further action.

Biodegradations of dangerous harmful substances in the environment are important prospective methods, where complex compounds and pollutants harmful to the environment are broken down into simpler (harmless) substances by biological action of living microorganisms. The principle of biodegradation technologies is the optimization of nutrient ratios (to support the growth of selected microorganisms able to degrade target contaminants) and the application of appropriately selected isolated strains of microorganisms with the appropriate biodegradation capability [12].

Biological methods of decontamination use their own or inoculated microorganisms (fungi, bacteria and other microorganisms) to break down (metabolize) organic pollutants contained in soils, wastes, or waters.

When applying biodegradation methods, account should be taken of the fact that this process is very complex. Success or failure depends primarily on the following factors [13–15]: chemical (type of contaminant, environmental pH, concentration of macro and microbiological elements, water content, chemical composition of contaminated material, chemical composition and concentration of suitable nutrient solutions, etc.), microbiological (degradation activity of microorganisms), and physical (temperature, solubility in water, sorption to solid particles).

Given that each of the above-mentioned factors impact the course of biodegradation, it is obvious that, when designing technological procedures and their applications, these factors must be taken into account and, if necessary, modified so that they limit the biodegradation process as little as possible.

Wastewater samples both with and without physical pre-treatment were subject to laboratory biodegradation experiments in the premises of the Department of Environmental Engineering of VSB – Technical University of Ostrava. A mixture of *Rhodococcus degradans*, *Rhodococcus rhodochrous*, and *Rhodococcus erythropolis* bacteria obtained from the Czech collection of microorganisms kept by the Faculty of Science of Masaryk University in Brno has been used for biodegradation. The Czech collection of microorganisms has a considerable spectrum of various types of microorganisms, together with a supporting database which includes their degradation abilities and specific cultivation properties and conditions.

Part of the samples was biodegraded without pre-treatment; part was subject to physical pre-treatment before the actual biodegradation on the equipment for physical pre-treatment in the laboratories of TGM WRI. For pre-treatment, the effect of an electrostatic field was tested with different exposure times, voltage in the range of kV, electric current in the range of mA.

The actual biodegradation took place for three weeks. Afterwards, the samples were filtered and special chemical analyses were performed. Due to the characteristics of the given wastewater sample, approximately 70 substances from the PPCP group (mostly pharmaceuticals) were selected for chemical determinations.

The first series of experiments indicate that just with the help of an electrostatic field, the content of active ingredients in many pharmaceuticals can be reduced (e.g., carbamazepine, celiprolol, clarithromycin, diclofenac, hydrochlorothiazide, iohexol, iomeprol, irbesartan).The combined technological procedure (physical treatment with an electrostatic field and biotechnologies with the help of selected strains of bacteria) appears to be very promising as a significant part of the entire spectrum of monitored substances has been reduced. Physical pre-treatment significantly increases the efficiency of subsequent biotechnologies by tens of per cent. The change (increase) in the efficiency of biodegradation of selected pharmaceuticals using an electrostatic field compared to biodegradation without the use of an electrostatic field is shown in the graph (*Fig. 3*).

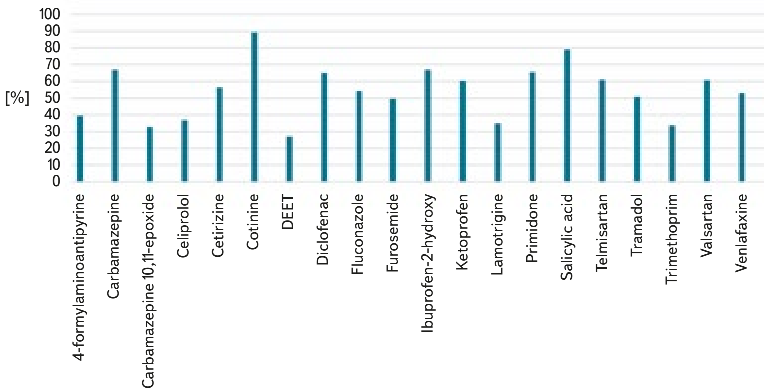

Fig. 3. Change/Increase in biodegradation efficacy of selected pharmaceuticals using electrostatic field versus biodegradation without applying an electrostatic field [%]

Experimental activities have verified that the combination of physical pre-treatment and biodegradation can be carried out gradually, or, if appropriately chosen mode, in the simultaneous synergy of both processes.

This is a presentation of the first results of experimental activities, which means that it is early to draw final conclusions. Individual functional elements of the experimental device are still in the process of refinement (e.g., reaction cassette space, sample circulation, pump with operation control). The equipment for physical wastewater treatment with a high voltage source was prepared for technical inspection. Audit reports are being issued for the experimental equipment and the HV source. A utility model application is planned to be submitted for the registration of finally refined reaction space of the device.

It can be stated that the combination of physical pre-treatment and biodegradation procedures appears to be promising in terms of effectiveness and spectrum of action.

Experimental laboratory tests are currently being performed to improve functionality, determine conditions of use of the equipment to reduce selected substances (pharmaceuticals) in real samples of wastewater from municipal wastewater treatment plants alone or in combination with selected biotechnologies.

DISCUSSION AND CONCLUSION

Topical issue in water management sector is wastewater purification from micropollutants, which would reduce the load on nature caused by anthropogenic activities and, at the same time, enable to reuse water, which is why new techniques and technologies are welcomed and, at the right time, also supported by society within the framework of fulfilling the goals of sustainable development.

The current physical waste treatment equipment is modified to use an electrostatic field to reduce the content of selected persistent pollutants in wastewater. The equipment is currently constructed as a test laboratory device, but in the future it shall become an industrial device.

Currently, cooperation is being built with other research institutions (especially with remote sites at universities) and trial testing of wastewater is performed as part of user optimization of the equipment. Negotiations with manufacturers of test laboratory and industrial technical equipment (especially WWTPs) are underway. A network of professional partners is constantly expanding. To prepare a marketing strategy for the product, an important and strong strategic partner is being sought for the further development and application of this equipment.

Acknowledgements

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Wastewater analysis as a tool for investigating drug abuse in education institutes

VĚRA OČENÁŠKOVÁ, DANICA POSPÍCHALOVÁ, EVA BOHADLOVÁ, DIANA MAREŠOVÁ

Keywords: wastewater based epidemiology — illicit drugs — THC — methamphetamine — amphetamine — MDMA — cocaine — benzoylecgonine — nicotine — cotinine — trans-3-hydroxy-cotinine — ephedrine — school institutions

ABSTRACT

The wastewater based epidemiology (WBE) approach to wastewater has long been used for monitoring drug consumption, especially in urban agglomerations. In this pilot project, it was applied to detect drug use in selected educational establishments. The tests took place in both primary (age 6–15) and secondary schools (age 12–19). The focus was on illicit drugs (marijuana, methamphetamine, amphetamine, cocaine, and ecstasy), as well as the licit drug nicotine and its metabolites. Ephedrine was also monitored. Grab samples were taken before the start of classes between 7:30 and 8:05 a.m., and during the so-called big break, i.e., between 9:30 and 10:00 a.m., or 10:30–11:00 a.m. Sampling was carried out on two dates, at the beginning of June and at the end of September/beginning of October 2022. There were positive findings for THC, ephedrine, methamphetamine and nicotine metabolites, primarily trans-3-hydroxy-cotinine. In accordance with the possibilities of the pilot project, the number of monitored schools was very small. In order to objectively determine the situation in educational facilities, it would be appropriate to monitor a more representative group, which would include, for example, vocational schools. It is also worth considering another method of sampling wastewater, e.g., several hours' composite samples. However, in many educational institutions, this method may not be feasible.

INTRODUCTION

The multidisciplinary scientific field of wastewater based epidemiology (WBE) has been applied for more than 20 years. It is a regular part of the detection of the consumption of licit and illicit drugs in the population, on which it has been focused since the beginning [1–3]. The results of the international monitoring of drug use in selected urban agglomerations are regularly published on the website of the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) [4, 5].

Today, municipal wastewater can provide comprehensive information about the health status of the population, the population's exposure to environmental contaminants, diet, the occurrence of diseases, and the consumption of pharmaceuticals [6].

The Covid-19 pandemic greatly contributed to highlighting the importance of wastewater based epidemiology, as SARS-CoV-2 virus particles were excreted by the infected population into wastewater. Detecting these particles in wastewater and measuring their concentration can serve as a tool for early warning before the onset of the disease because these particles are excreted even before the typical symptoms of the disease [7, 8].

In addition to the now common monitoring of the consumption of selected licit and illicit drugs in urban agglomerations, their use can also be monitored in individual buildings in a similar way. Here, above all, an ethical approach is very important as it could very easily lead to stigmatization of the tested institutions [9, 10]. Through wastewater analysis, drug use has been monitored, for

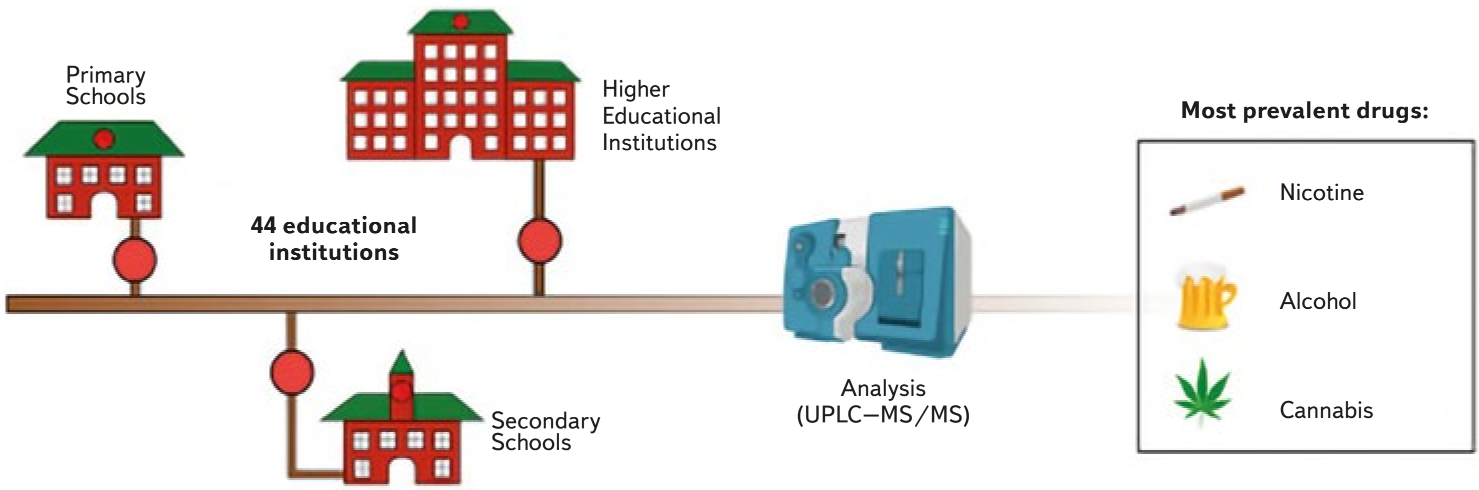

Fig. 1. Graphical representation of monitoring in educational facilities (Source: [15])

example, in prison facilities [11, 12], educational facilities [13–17], as well as at individual events (music festivals) [18].

In TGM WRI hydrochemical laboratories, samples and analyses have been carried out both in prisons and school facilities; therefore, the expert team has experience in this area. The results have generally not been published [19] for the above-mentioned ethical reasons, or because they are the outputs of commercial orders, to which TGM WRI does not have the default rule. The graphical presentation of monitoring is shown in *Fig. 1*, which was taken from [15].

METHODOLOGY

An accredited determination method, fully automated on-line solid phase extraction, and analysis by high-pressure liquid chromatography coupled with tandem mass spectrometry (on-line SPE and LC-MS/MS) were used to analyse illicit drugs in wastewater from selected school facilities, working in ESI + or ESI – mode (electrospray ionization), depending on the nature of the monitored substances. The method is based on procedure published by Postigo et al. [20]. In cooperation with the staff of the selected educational institutions, the possible sampling points were inspected. In one case, it was not possible to take samples for safety reasons (the sampling point was very difficult to access), so another facility was approached. In all selected schools, the sampling was carried out twice in the same year.

Wastewater sampling and analysis

Four schools from Prague and its immediate surroundings were selected for the pilot project: two primary schools and two secondary schools. Sampling was carried out at the sewage water outlet from the monitored facility (sewer connection); in one case, two sampling points were chosen due to the layout of the school. *Fig. 2* shows an example of a sampling point. Sampling took place in June and in September/October 2022. These were grab samplings that were carried out in the morning after the school opened before the start of classes between 7:30 and 8:05 a.m. and during the so-called big break, i.e., at 9:30–10:00 a.m., or 10:30–11:00 a.m. The samples were transported to the laboratory immediately after collection and stored in a refrigerator at 4–8 °C; if it was not possible to process them within 48 hours after collection, they were kept frozen at -20 °C until the actual analysis.

Fig. 2. Example of a sampling point on sewage connection (Source: TGM WRI archives)

The detailed procedure is described in [21]. After thawing and conditioning at room temperature, solid impurities were removed from the samples by filtration through membrane filters. A mixed solution of internal standards, including isotopically labelled standards, was added to the filtered sample. Furthermore, the samples were extracted, purified, concentrated on SPE column, and analysed by high-pressure liquid chromatography coupled to tandem mass spectrometry (on-line SPE-LC-MS/MS). The system worked in ESI + or ESI – mode depending on the type of analyte.

Marijuana was monitored in the samples through the standard analysed metabolite of THC, 11-Nor-9-carboxy-delta-9-THC (THC-COOH), i.e., the human metabolite and main excretory product of THC, which is the active substance of marijuana; these findings were as expected. Ecstasy (MDMA, 3,4-methylene-dioxy-methamphetamine) was also found, as were methamphetamine (Pervitin) and its metabolite amphetamine, cocaine and its human metabolite and the main product benzoylecgonine excreted in the urine, ephedrine, and nicotine and its metabolites cotinine and trans-3-hydroxy-cotinine. In the Czech environment, amphetamine is considered from the point of view of wastewater analysis primarily as a metabolite of methamphetamine, not as a drug used independently. THC-COOH was analysed by the on-line SPE-LC-MS/MS method in ESI – mode; the other substances were analysed by the on-line SPE-LC-MS/MS method in ESI + mode. The measured results (chromatograms) were subsequently evaluated by the corresponding instrument software and manually checked by the analyst.

RESULTS AND DISCUSSION

Due to the limited possibilities of this pilot project, samples were taken only in four facilities. *Tab. 1* summarizes all measured results. For ethical reasons, the results are presented anonymously. Facilities A and C are secondary schools (age 12–19), facilities B and D primary schools (age 6–15). The number of pupils in the schools varies between 500 and 1,000. The results are given in concentrations (ng/l) and cannot therefore be compared with each other. Wastewater flows were not measured at the time of sampling. Therefore, it is not possible to express the results as, for example, ng/day/1,000 inhabitants. Nevertheless, it is possible to conclude whether drugs are a problem in the monitored school.

We assumed that marijuana would be the most commonly abused drug. It was analysed in all monitored facilities, but not in all samples. The highest concentrations of this drug were found in facility C, but only in the sample taken on 3rd October 2022. It is possible that the date of the first sample (1st June 2022) was not chosen appropriately because on this day (Children's Day) some schools had special programmes. In other schools, much lower concentrations were found, and always only in one sampling at one sampling point. Ecstasy (MDMA) was not present in any sample, nor was cocaine and its major human urinary metabolite benzoylecgonine. Methamphetamine (Pervitin) was found in a total of four samples from facilities C and D, in single to double digits of ng/l. Amphetamine was also not present in any of the analysed samples. It fully corresponds to the fact that, in the Czech Republic (from the point of view of wastewater analysis), amphetamine is considered a metabolite of methamphetamine, and at the concentrations of methamphetamine found, the amount excreted is below the limit of quantification of the method used.

Metabolites of the licit nicotine drug cotinine, and especially trans-3-hydroxy-cotinine, were found in almost all monitored samples. In this case, however, it can be assumed that school employees contribute a significant share of the excreted amounts.

In total, ephedrine was determined in five wastewater samples. Ephedrine is a precursor for the production of Pervitin, but it is also part of flu and cough preparations, as it relaxes the airways and relieves flu symptoms. In combination with caffeine, it is an excellent fat burner. It is also used as a weight loss medication and is part of preparations designed to build muscle and improve the physical abilities of athletes [22]. It is a prohibited doping substance. In the building of the school facility where the highest concentrations of this substance were measured, the fitness centre is open to the general public

Tab. 1. Complete results of selected drug monitoring in educational facilities

Facility	Sampling			Monitored substance									
	date	location	time	THC–COOH	ecstasy (MDMA)	methamphetamine	amphetamine	cocaine	benzoylecgonine	nicotine	cotinine	*trans-3-hydroxy-cotinine*	ephedrine
A	13. 06. 2022	sewer connection	7:45–8:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	1,830	< 2.4
	13. 06. 2022		10:30–11:00	21.9	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	2,660	7,090	< 2.4
	10. 10. 2022		7:45–8:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	1,700	< 2.4
	10. 10. 2022		10:30–11:00	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	4,780	21,700	508
B	06. 06. 2022	sewer connection	7:45–8:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	794	2,130	< 2.4
	06. 06. 2022		9:40–10:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	2,430	6,360	< 2.4
	26. 09. 2022		7:40–8:05	46.4	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	1,210	< 2.4
	26. 09. 2022		9:40–10:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	< 40	< 2.4
C	01. 06. 2022	sewer connection	7:40–8:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	859	2,770	< 2.4
	01. 06. 2022		9:40–10:00	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	3,140	11,900	< 2.4
	03. 10. 2022		7:40–8:05	8,480	< 3.0	13.5	< 1.1	< 2.5	< 3.5	< 300	< 50	1,690	25.6
	03. 10. 2022		9:40–10:05	305	< 3.0	6.1	< 1.1	< 2.5	< 3.5	5,920	5,110	17,800	7,360
D	26. 05. 2022	transfer pump	10:10–10:15	16.2	< 3.0	11.3	< 1.1	< 2.5	< 3.5	< 300	2,540	8,240	30.8
	26. 05. 2022	sewer connection	7:40–8:00	6.2	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	556	5,090	< 2.4
	26. 05. 2022		9:40–10:05	< 1.3	< 3.0	3.8	< 1.1	< 2.5	< 3.5	< 300	< 50	< 40	< 2.4
	24. 10. 2022		7:40–8:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	< 40	< 2.4
	24. 10. 2022		9:40–10:05	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	< 50	< 40	< 2.4
	24. 10. 2022	transfer pump	9:30–9:35	< 1.3	< 3.0	< 0.9	< 1.1	< 2.5	< 3.5	< 300	1,990	6,780	10.3

from early in the morning, so the visitors of this centre may therefore be mainly responsible for the high concentration of ephedrine in the wastewater.

Due to the small number of samples, no statistical evaluations can be performed; however, it was not the goal of this very small-scale pilot project.

When comparing the findings obtained in the project with the findings in other monitored schools as part of commercial contracts implemented before, it can be stated that, with a high probability, drug consumption does not represent a significant problem in the educational facilities tested in the project. Only in the facility C would it probably be appropriate to pay more attention to drug issue. However, the measurement would need to be repeated.

The results are difficult to compare even with the references. Zuccato et al. [13] report results in mg/day/1,000 inhabitants, while other authors [14, 17] monitor universities; Verovšek et al. [15] are only concerned with the identification of drugs in the wastewater of the tested schools. The only comparison is thus offered by another publication by the authors cited above [16], which contains the results of the research of drug abuse in 44 school facilities in Slovenia. For example, in primary schools in urban areas, the concentration of THC-COOH ranges between 4.44 and 1,460 ng/l; the main cocaine metabolite benzoylecgonine (28.8–1,640 ng/l) was also determined in a number of schools. Ecstasy was not found in any of the primary schools, nor was methamphetamine. In the case of benzoylecgonine and methamphetamine, there is a difference between Czech and Slovenian schools. In Czech schools, benzoylecgonine was not found in any case, but methamphetamine was detected in one case.

If this pilot project were to be followed up by another, more extensive project, in which it would be possible to involve other types of educational facilities (e.g., apprenticeship and vocational schools as well as higher vocational schools), it would be appropriate to verify another sampling method (e.g. collection of several hours' composite samples) and, simultaneously, to determine wastewater flows at the time of sampling. Then the results could be better compared with each other. It would also be interesting to increase the frequency of sampling in individual facilities, or to monitor one sampling point, for example, for a whole week.

It would be interesting to add mitragynine (the active alkaloid of kratom) to the monitored substances; due to its easy availability and widespread use among young people, it is currently receiving a lot of attention from addictologists.

CONCLUSION

The pilot project fulfilled its purpose. We verified the entire procedure required for the collection and analysis of wastewater from educational facilities, from the selection of facilities, communication with their management, on-site inspection, and selection of a suitable sampling point on the sewer connection, including possible consultation with workers operating the sewer network. In older buildings in particular it is not always easy to find a sampling point. In all tested schools, drugs were found in measurable quantities, mostly only occasionally. In accordance with the assumption, it was mainly marijuana. Methamphetamine was found in two schools in concentrations that were similar to most schools tested by the TGM WRI hydrochemical laboratories as part of commercial contracts.

The licit drug nicotine and/or its metabolites cotinine and trans-3-hydroxy-cotinine were determined in almost all samples. Comparison with previous analyses is not possible because it was only later included in the analytical method of determination. Similarly, we do not have the possibility to compare the findings of ephedrine. Ephedrine is part of over-the-counter cold medicine, but it is also part of preparations used to build muscle and improve the condition of athletes. As one of the tested schools has a publicly accessible fitness centre open from early in the morning, and it is not possible to ensure sampling at the sewer connection so that sewage from the fitness centre is not part of the sample taken, it can be assumed that visitors to the centre significantly contributed to the finding of high concentrations of ephedrine in the sample.

When selecting school facilities for a possible future project, it is therefore necessary to pay attention to whether extracurricular activities intended for the general adult public (lifelong learning, language courses, exercise courses, etc.) could significantly influence the findings of tested substances in wastewater.

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Methods of collection and management of biodegradable municipal waste in selected countries of the European Union and current results from moisture loss measurements

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Keywords: biological waste — food waste — collection — treatment — moisture loss reporting — circular economy

ABSTRACT

The ever-increasing amount of waste, including biological waste, is causing serious problems in modern society, such as the filling of municipal waste landfills, which subsequently produce greenhouse gases. For society to deal with this problem, the legislation of some member states of the European Union (EU), including the Czech Republic (CR), has introduced new obligations to support the prevention of waste generation and its increased recycling and reuse. In 2020, the European Commission released the Circular Economy Action Plan, which provides guidelines for many countries on renewables and waste. However, in some cases the current measures are not enough. A new law on waste was adopted in the Czech Republic, which specifies the obligation to sort biological waste for legal entities and natural persons who allow physical persons to dispose of municipal waste in their establishments.

This article brings the current interim results of research project SS02030008 *"Centre of Environmental Research: Waste Management, Circular Economy and Environmental Security (CEVOOH)"*. It deals with a brief description of biodegradable municipal waste (BMW) collection in some EU countries and draws general conclusions from the facts found. It also deals with the current results of measuring the moisture loss of biological waste in order to fulfil the obligation of the Czech Republic to report the quantity of this waste in its "fresh" state.

INTRODUCTION

Methods of collection and management of biodegradable municipal waste (BMW) are of great importance (not only) in the EU from the point of view of environmental protection and sustainable waste management. Biodegradable waste (BW) includes organic waste such as food scraps, garden waste, leaves, coffee grounds, and other organic materials that can be naturally broken down by microorganisms. The prevention, effective separation, and collection of such waste are key to reducing the amount of waste that ends up in landfills, while representing an important step towards sustainable waste management.

The legislation that governs the issue of biological waste in the EU and the Czech Republic includes several standards that represent a framework for Member States and set goals and limits for waste collection and management. Key ones include:

- EU Landfill Directive – Article 5 sets the amount of BMW that Member States can place in landfills in individual years (in percentages). At present, according to the Directive, the maximum amount of BMW deposited in landfills in 2020 should be no more than 35 % of the weight of the total amount of BMW produced in 1995. This target is also set by the Czech Republic in the current Waste Management Plan of the Czech Republic.
- EU Landfill Directive – Article 3a generally stipulates the obligation that from 2030 no waste suitable for recycling or other use, in particular municipal waste, is accepted into landfill, with the exception of waste for which landfilling leads to the best environmental outcome in accordance with Article 4 of Directive 2008/98/EC.
- EU Waste Framework Directive – Article 22 establishes the obligation to introduce measures by 31 December 2023 at the latest to ensure that biological waste is either sorted and recycled at source, or that it is subject to sorted collection and is not mixed with other types of waste.
- At the national level, there is already a ban on the storage of BW and outputs from its modification or processing, namely in Section 41 paragraph 3 letter b), with the exception of waste with a minority share of biodegradable components, or outputs from the treatment or processing of BW, which cannot be processed in any other way.
- In point D of Annex No. 4 to Decree No. 273/2021 Coll., on the details of waste management, the requirements are set for BW with a minority share of biodegradable components and outputs from their treatment which can be deposited in a landfill.

One of the fundamental obligations that will affect the sorting of biowaste in municipalities is the obligation of municipalities in the following years to forward an increasingly higher percentage of usable components of municipal waste for recycling (60 % from 2025, 65 % from 2030, and 70 % from 2035). Fulfilment of this obligation will also be conditional on ensuring the sorting of a sufficient amount of biowaste.

However, there is a considerable difference between individual EU states in the area of BW collection and management.

A total of 199,558 links were found in the Web of Science database during the analysis of publications on methods of sorting and collecting BW in municipalities. As can be seen in *Fig. 1*, publication activity is increasing at a gradual pace, depending on the approaching deadlines of the restriction set by the adopted EU legislation.

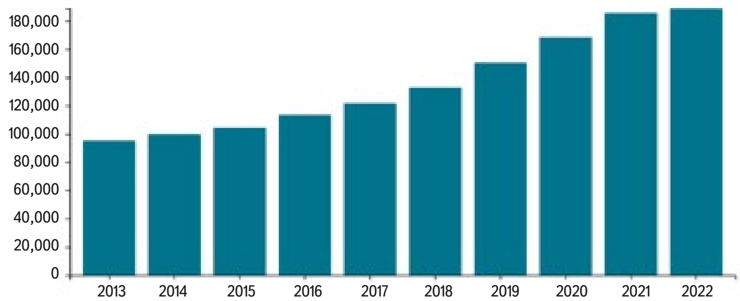

Fig. 1. Graph of publication activity in the Web of Science database (Source: Web of Science database)

Fig. 2 shows the distribution of the countries with the greatest publication activity. The European countries are represented by England, Italy, Germany, France (in descending order).

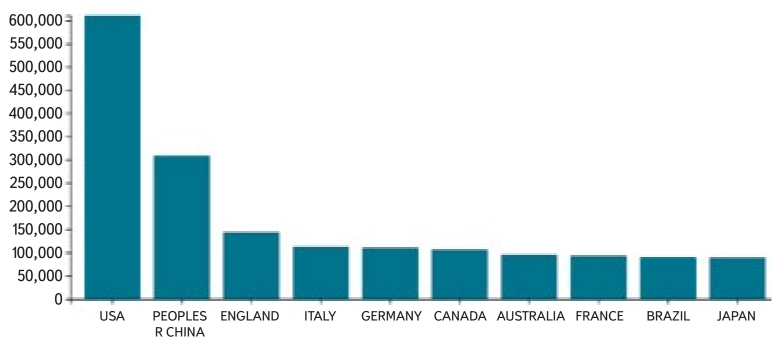

Fig. 2. Graph of the publication activity of the most important countries in the Web of Science database (Source: Web of Science database)

A search of the professional literature shows that countries that have been relying on separate systems for the collection and processing of biological waste for more than 15 years include, for example, Austria, Switzerland, Germany, the Netherlands, Flanders (Belgium), Sweden, and Norway. These countries have well-developed infrastructure and legislative frameworks that support the sorting and composting of biowaste [1].

Summary of biowaste collection and management methods in selected European countries

Specific and (from our point of view) key aspects of successfully preventing the creation, sorting, and processing of BW (including food waste), and thereby fulfilling the principles of the circular economy, differ in individual EU countries (*Tab. 1*).

The following summary describes some collection methods and motivating residents to fulfil their obligations in selected European countries:

AUSTRIA

Austria has a developed biowaste collection system with approximately 70 % coverage of the population. Austrians throw away a fifth of all the food they buy, of which the loss of 14.5 %, which amounts to one billion Euros per year, is partially or completely avoidable [2]. Austrian consumers are responsible for almost half of the total waste, while agricultural production is responsible for around 30 % of total food waste. Farmers, producers, retailers, and food service operators (e.g., hotels, restaurants, caterers) in Austria either produce too much food that never reaches consumers, or food losses arise from inefficient storage, transport, or planning the demand [3] .

Food losses and waste are never local – fluctuations are caused by market prices of food and contribute to global carbon dioxide emissions. Countries like Austria, with developed infrastructure and available economic and social resources, are pioneers in creating solutions to the issue of systematic food waste. In Austria, biowaste collection is developed and integrated into the overall waste management system. Citizens have at their disposal special collection containers for biowaste, which are placed in municipalities and in public spaces, regularly emptied, and their contents processed by composting. The motivation for residents is mainly high awareness and education about the importance of sorting and recycling waste, which leads to a high level of involvement. The waste is collected separately from normal municipal waste and subsequently processed using methods such as composting and anaerobic digestion [4].

SWITZERLAND

Switzerland may have a reputation as one of the cleanest countries in the world, but with more than 90 million tons of waste produced annually (700 kg per person), it is one of the world's largest producers of waste. At the same time, however, thanks to the adopted waste management policy, it is one of the countries with the highest efficiency of its recycling programme. More precisely, the country achieves a recycling rate of up to 50 %; the remaining waste is further used to generate energy by incineration. Switzerland has a long tradition of waste sorting and BW forms an important part of the system, with composting being a common method of processing this waste [5]. We can consider the following aspects leading to such results:

1. Prevention – influencing consumer behaviour; consumers-waste producers are informed not only about the positive aspects of the right way of shopping and timely consumption of food, but are also familiar with the fee they will pay in the case of generated waste.
2. Intervention – support consumers in recycling. Part of the intervention plan is an active effort to (a) make recycling infrastructures accessible and easy to use by the population and (b) enable citizens, with proper sorting, to dispose of waste for free, i.e., use of private/community composters/compost plants.
3. Consumer education – transfer of final responsibility to the producer according to the principle "The cost of waste disposal is borne by the person who produces it". This principle is implemented by taxing the amount of waste produced by each individual. In addition, only official bags provided by the authorities can be used for the disposal and collection of municipal waste. These are available in different sizes and price per litre of content (e.g., €0.033/litre in Bellinzona).

Authorities are responsible for monitoring and sanctioning any illegal disposal of waste. The same applies to littering or leaving small amounts of litter in public places. This activity is prohibited and punished by the authorities. Although "legal punishment" has a deterrent effect, real change in consumer behaviour can only be achieved through proper education. Raising awareness is essential in solving a social issue such as littering. In particular, depending on the target age, different strategies can be implemented, such as education – at an early stage in public schools, later through public campaigns [6].

We can say that although Switzerland has a solid foundation and has implemented a successful waste management strategy, it continues to focus on intervention at the source of the problem, i.e., waste prevention, which remains a key area to be addressed in the future. The Swiss experience shows that a more informed citizen does not automatically mean a more informed and engaged consumer, which is why educational campaigns to promote

Tab. 1. Food waste production by sector of activities, 2020 (tonnes of fresh mass; numbers in italics are estimates). (Source: https://1url.cz/ruEEQ)

	Total food waste	Primary production	Processing and manufacturing	Retail and other distribution of food	Restaurants and food services	Households
Belgium	2,881,897	38,699	1,862,177	73,591	88,333	819,097
Bulgaria	596,844	228,472	156,435	15,708	14,375	181,854
Czechia	*972,445*	*27,022*	*100,339*	*64,394*	*37,941*	*742,749*
Denmark	1,286,488	66,452	596,599	99,500	62,544	461,392
Germany	10,922,321	190,203	1,612,505	762,352	1,860,980	6,496,282
Estonia	166,513	23,612	31,622	19,976	10,739	80,564
Ireland	770,316	70,413	219,453	60,894	178,507	241,048
Greece	2,048,189	372,204	375,158	150,472	220,032	930,323
Spain	4,260,845	845,620	1,419,257	348,219	213,023	1,434,726
France	*9,000,000*	*1,059,000*	*1,926,000*	*800,000*	*1,096,000*	*4,119,000*
Croatia	286,379	40916	9,866	4,180	15,072	216,345
Italy	8,650,456	1,270,638	510,018	343,535	193,915	6,332,349
Cyprus	*354,021*	*43,564*	*169,706*	*50,268*	*27,145*	*63,338*
Latvia	275,304	32,487	36,107	14,765	35,436	156,509
Lithuania	*382,665*	*81,202*	*28,057*	*27,342*	*4,495*	*241,570*
Luxembourg	92,580	7,384	10,692	8,525	8,739	57,240
Hungary	905,068	16,587	187,391	41,952	19,331	639,806
Malta	79,589	759	4,668	3,910	23,016	47,235
Netherlands	2,811,000	463,045	1,031,407	209,805	83,035	1,023,708
Austria	1,211,534	13,879	173,734	84,326	201,956	737,639
Poland	4,002,099	670,547	544,942	320,396	190,293	2,275,921
Portugal	*1,890,712*	*101,384*	*61,719*	*214,233*	*237,486*	*1,275,891*
Romania	not available					
Slovenia	143,570	93	10,757	15,290	42,666	74,764
Slovakia	455,587	71,889	4,113	15,825	7,110	356,650
Finland	641,258	48,011	162,278	57,555	77,914	295,500
Sweden	*905,000*	*22,000*	*53,000*	*97,000*	*98,000*	*635,000*
Norway	769,967	162,158	29,088	61,281	97,547	419,893
Total	58,512,559	6,067,377	11,806,452	4,079,709	5,275,265	31,283,755

sustainable consumption are constantly organized there. For truly effective efforts, they recommend focusing on both sides of the market, i.e., the "consumer" and the "producer". The Swiss government is trying to take measures at the regulatory level and penalize those who produce products that contribute the most to waste generation (e.g., products with a particularly short shelf life or excessive packaging) [7].

GERMANY

Every year, around 15 million tons of BW are processed in composting and fermentation or biogas plants in Germany. In essence, it is the contents of organic waste bins, BW from gardens and parks, waste from markets, and other BW from various sources. In some regions of Germany, the "Gelber Sack" approach is applied, which is a system where different types of waste are packed in special yellow bags and collected regularly (*Fig. 3*). A significant incentive for residents is the system of refunding fees for returning packaging, which stimulates proper waste sorting. In 2020, about 5 million tons of organic waste and about 5.7 million tons of garden and park waste were separately collected via organic waste bins in Germany, which corresponds to 129 kilograms per inhabitant per year. Germany is known for its advanced and carefully organized waste sorting system. Here, BW is also collected separately in green or brown containers and is subsequently used for composting or anaerobic digestion [8–10].

Fig. 3. Yellow bags "Gelber Sack" used in Germany
(Source: https://de.wikipedia.org/wiki/Gelber_Sack#)

THE NETHERLANDS

The Netherlands places great emphasis on waste recycling. BW is collected and processed in order to minimize its impact on the environment. In 2018, for example, 56 % of all municipal waste was recycled, and since then this number has been constantly increasing [11]. In the Netherlands, the "gescheiden afvalinzameling" system (separate waste collection) is often used. Citizens have separate collection containers for biowaste at their disposal, which are regularly emptied. The country invests in awareness and education campaigns, which helps increase awareness and involvement in waste sorting. It considers composting to be key BW (food) processing, which takes place in most municipalities. Food is sorted and stored in green containers (groenbak), which are collected regularly, or residents are directly motivated to buy composting containers for food and to use compost, even in cities on balconies and terraces.

FLANDERS (BELGIUM)

The total amount of food waste produced in all sectors of the food chain in Flanders amounts to almost 1.3 million tonnes per year, of which 71 % is collected separately and 29 % is part of mixed waste. The highest production of food waste comes from the food industry (122 kg/capita), which is important in Flanders – 55 % of food produced in Flanders is intended for export. Households produce 61 kg/capita, which is below the EU average (70 kg/capita) [12–14]. Flanders is a region in Belgium with a very advanced waste sorting system; separate collection of BW is mandatory. Citizens have access to biowaste containers that are regularly emptied and composted. An important part of success is the active involvement of local communities and municipalities, which promote sorting and talk about the benefits of recycling. Biodegradable waste is collected separately and processed exclusively for the purpose of producing compost.

SWEDEN

Although Sweden produces an average of 467 kg of waste per person and almost 4.4 million tons of household waste per year, the key to the country's success is high public awareness of the benefits of recycling, as well as an efficient collection system. The process starts with households and businesses sorting waste into hazardous and recyclable materials, separating food waste, metal, plastic, paper and glass packaging, newspapers, electronics, tyres, and batteries. To encourage everyone to join the system, Sweden has built waste collection points within 300 metres of all residential areas. While some of this waste is recycled, almost half of the waste produced (typically a mix of energy-rich materials such as paper, plastic, and biomass) is taken to waste-to-energy facilities, where it is converted into electricity. Similarly, food waste is turned into climate-friendly biogas used to run public transport buses and heat apartment buildings.

Key aspects of promoting sorting and recycling in Sweden are:

1. Household awareness of the importance and benefits of sorting waste
   In the vast majority of Swedish households, waste is sorted at its source. The awareness and dedication of the citizens of Sweden is a key success factor that has led to Sweden being considered one of the global leaders in sustainable waste management. Most households in Sweden sort their waste into the following fractions: food waste, metal, plastic, paper and glass packaging, newspapers, electronics, tyres, and batteries. Important steps are currently being taken to increase the reuse and repair of goods. Extended producer responsibility creates incentives to reduce waste production and increase material recycling.

2. Converting waste to energy
   A large part of the waste generated in Sweden is incinerated in facilities intended for its energy use in the field of water district heating, as well as electricity generation. As a result of all the measures taken, less than one percent of the total amount of waste produced in the country is landfilled. Urban planning is an important tool when municipalities want to work on waste management according to the required hierarchy.

3. Waste management in Swedish legislation
   The legal basis for the Swedish waste management system is laid down by both Swedish and European waste legislation. In Sweden, landfilling is the least preferred solution. The preferred option is to prevent waste and reuse and repair products. If waste is still generated, the main goal is to recycle the materials. Sweden is one of the leading EU countries in BW management. Local sorting and collection systems support recycling and biogas production [15–17].

NORWAY

Norway, like other Nordic countries, has effective BW collection and processing systems, with composting and anaerobic digestion being common methods. Norway is an example of using BW as an energy source. There are a number of anaerobic fermentation facilities in the country that process gastro-waste and the resulting biogas is used as a renewable energy source [18, 19].

ITALY

In Italy, the sorting and collection of BW is regulated regionally and may vary from municipality to municipality. Some have a system of bio-waste bins, while others promote composting in households and public places [20, 21].

FRANCE

In some parts of France, BW collection is well organized, while in other areas there is room for improvement. Some cities collect food waste using special containers. The activities of start-ups and civic associations play an important role here [22–27].

SYNTHESIS

From the above, the following key aspects necessary to ensure the fulfilment of obligations in BW sorting follow. Specifically, they are:

- Information campaigns: most countries organize information campaigns and educational activities that explain the importance of sorting and proper BW management.
- Financial incentives and penalties: some countries use financial incentives through a system of waste charges. Citizens who sort well may have lower fees. Conversely, if the waste is sorted incorrectly, penalties and fines may be imposed.
- Quality infrastructure: countries with good infrastructure, including accessible dustbins and collection containers, make it easier for citizens to sort properly.
- Support for composting: some countries support home composting and provide citizens with composters for free or at reduced prices.

All EU countries, including the Czech Republic, are obliged to sort biodegradable components of municipal waste by the end of 2023. This obligation applies to municipalities and towns, which must achieve a minimum level of sorting that supports the use of waste and the reduction of landfill.

Production of individual components of biowaste differs depending on whether it comes from family homes or housing estates. In housing estates, green waste is generated in limited quantities, while kitchen waste predominates. Seasonality also has an impact – green waste production increases during the warm months, while kitchen waste production remains stable throughout the year.

Currently, together with BW from the urban greenery and garden maintenance, it is possible to collect plant components of kitchen and food waste from households. Biowaste collection systems are focused on all plant components, but above all on the green component, which makes up only about a third of the total biowaste collected. Kitchen waste does not have its own collection system, although the Ministry of the Environment sets the obligation to collect at least the plant component. It is important to plan the collection system to include all components of biowaste, including kitchen waste.

A key aspect is the purity of biowaste, which plays a vital role in its processing. Regardless of whether the waste is intended for processing in a composting plant or a biogas station, the purity of the collected material is key. In order to ensure purity, it is important to prevent pollution from sorted biowaste through education of residents and limiting access to biowaste containers, for example by locking them. Sorting technologies exist, but they are expensive. In the Czech Republic, the sorting of most biowaste in composting plants is carried out in a not very sophisticated way; therefore, during the growing season, a large amount of biowaste can accumulate in composting plants, which is not effectively sorted.

Waste sorting systems are key to preventing contamination of biowaste with pollutants. EU Member States may waive the obligation of separate collection of biowaste in certain cases, for example in inner city areas where the logistics of separate collection may be difficult, or in sparsely populated rural areas. In these cases, alternative biowaste processing methods such as domestic, local, or community composting can be supported.

Some countries, including the UK, Italy, Finland, Ireland, Slovenia, Estonia, and France, have made significant progress in developing their biowaste collection and processing systems in recent years. On the other hand, some countries, including the Czech Republic, still need to improve their infrastructure and implement effective measures and legislation to meet EU requirements regarding biowaste sorting [28–30].

FACTORS AFFECTING THE EFFICIENCY OF THE SET BIOWASTE COLLECTION SYSTEM

The method of sorting BW, including waste from urban greenery maintenance, gardens, and food waste, is of key importance for the sustainable processing of this waste and environmental protection. From the above research, there are several factors that influence the success and efficiency of separate BW collection. These factors include:

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1. Motivating, communicating, and educating residents
   Motivation, communication and education of residents are key to a successful BW collection system. The methods of their implementation include:
   - Personal communication, campaigns, workshops, and training that are organized for citizens to inform them about the importance and correct way of sorting and collecting biowaste.
   - Instructions and educational materials that help citizens sort waste correctly.
   - Financial incentives, such as discounts on waste fees or rewards for correct sorting, which could motivate citizens to actively participate.
   - Punishment, i.e., sanctions or fines for those who do not comply with waste sorting obligations, and can serve as additional motivation to fulfil obligations in this area.

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2. Collection convenience
   - Delivery distance for which the principle applies – the closer the collection containers are located to households, the more probably people will actively use them. A longer distance may reduce willingness to participate in sorting.
   - Collection hygiene, i.e., ensuring the cleanliness of collection containers and their regular maintenance, which is important for minimizing odours and the occurrence of harmful microorganisms and other pests.
   - Cleanliness of collection containers and prevention of the spread of odours and development of mould; the odour from BW can be unpleasant, especially in the summer months. It can also cause problems with insects. Resolving these issues is important for acceptance of waste collection.
   - The influence of temperature, which determines the rate of decomposition of biological waste. In colder areas, decomposition may be slower, which may require more care when collecting. When choosing the location of collection containers, places that are shaded for most of the day should be preferred.

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3. Frequency of waste removal
   Frequent and regular emptying of collection containers minimizes odours and prevents the accumulation of waste, which leads to more convenient sorting for residents. Regular removal of BW is important for maintaining the cleanliness and hygiene of the collection points. Insufficient removal frequency can lead to over-filled containers and problems with insect. People are more motivated to sort if they are sure that their waste is collected regularly.

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4. Method of collection
   Outdoor vs. indoor waste bins: the provision of indoor collection containers can increase the convenience of sorting, especially in adverse weather conditions. In some cases, it may be appropriate to place containers indoors to minimize odour and aesthetic issues. However, outdoor containers are usually easier to access.
   Vented vs. non-vented waste bins: vented containers can minimize the development of unpleasant odours and mould.
   Waste bin size: the optimal size of collection containers ensures sufficient capacity while minimizing the long-term accumulation of waste that could lead to problems.

5. Method of home composting
   Composting bins: offering composting bins allows residents to do their own composting, reducing the amount of BW that would have to be removed. Providing compost bins to households can motivate people to sort BW more actively. These containers placed, for example, in gardens or on balconies allow easier composting.
   Community composters: The establishment of community composters provides the possibility of sorting waste even for those who do not have enough space for their own composting. These composters can be placed publicly in different parts of the city. This increases accessibility for a wider spectrum of the population.

Overall, we can say that the sorted collection of BW requires attention to details such as the location of collection containers, cleanliness, hygiene, and waste removal. It is also important to consider different collection methods, such as outdoor and indoor containers, as well as supporting alternative methods, such as community composters, which can increase the involvement and motivation of residents to actively sort waste.

EFFECT OF TEMPERATURE AND CONTAINER VENTILATION ON MOISTURE LOSS OF BIODEGRADABLE MUNICIPAL WASTE

To ensure the fulfilment of the Czech Republic's obligation regarding the notification of the occurrence of food waste, a requirement was established to report the amount of this waste in its "fresh" state. During the research survey that we carried out as part of the SS02030008 project *"Centre of Environmental Research: Waste Management, Circular Economy and Environmental Security (CEVOOH)"*, we obtained data from reports of the Slovak Ministry of the Environment regarding the collection of BMW. In order to verify their applicability for the Czech Republic, our project included a requirement to determine moisture loss during food waste storage in model conditions that correspond to common practice.

Since sorted food waste is normally collected at intervals of one to two weeks, we carried out two cycles of experiments, each lasting 14 days. Experiments were performed both with perforated and non-perforated containers, and the composition of food waste was consistent with what we found in previous analyses of mixed municipal waste, BMW and food waste [31]. Specifically, the food mix consisted of: fruits and vegetables 39 %; pastries, pasta, dumplings 24 %; meat, eggs including shells 6 %; dairy products 9 %; cooked meals 19 %, and beverages 3 %.

12-litre containers with lids were used to simulate the usual method of sorting and collection and, at the same time, to minimize the amount of spoiled food (*Fig. 4*).

Fig. 4. Food mixture at the beginning of the experiment and a perforated container with a lid at the experimental site (Source: TGM WRI)

The containers were stored in a place partially protected by trees from the sun and rain (*Fig. 5*).

Fig. 5. Placement of test containers (Source: TGM WRI)

The first measurement took place in April and the second in June. *Fig. 6* shows the course of BMW weight reduction under the stated measured minimum (average 5.1 °C) and maximum (average 13 °C) temperatures together with the measured air humidity (average 73.2 %) during the April experiment. Weight or the moisture content of the food waste in the perforated container decreased by 350 g within 14 days, or 7.5 % by weight compared to a non-perforated container with a BMW weight loss of only 50 g, i.e., 1.1 % of weight.

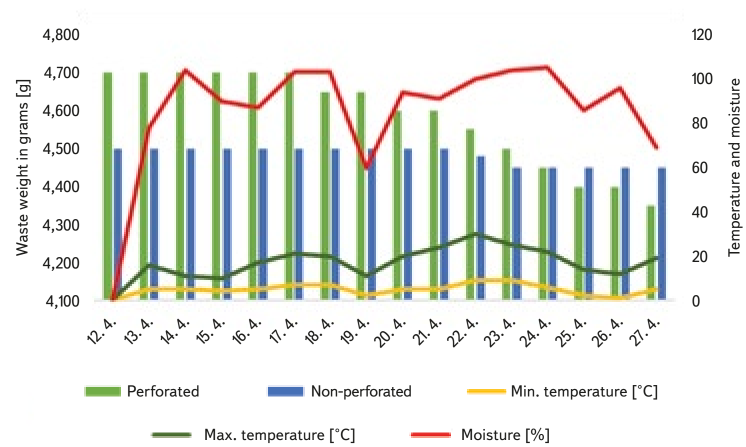

Fig. 6. Graph of moisture loss or weight of BMW during the April measurement (Source: TGM WRI)

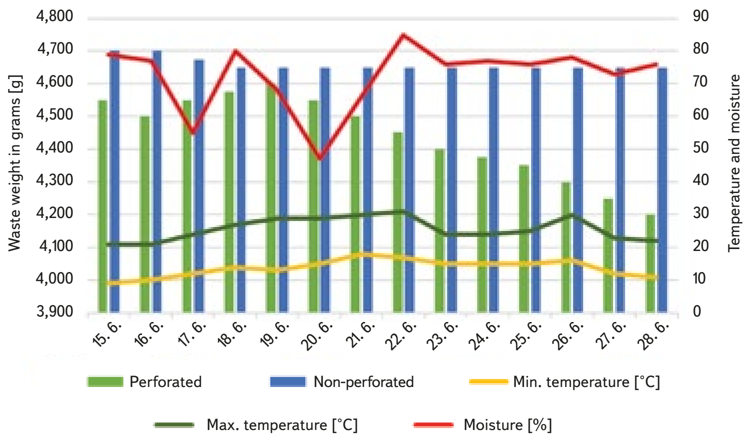

Fig. 7. Graph of moisture loss or weight of BMW during the June measurement (Source: TGM WRI)

In June, we repeated the measurements under the same conditions to find out the effect of temperatures on weight loss, or moisture. During the June measurement, when the minimum temperatures reached an average of 13.7 °C and the maximum 25.7 °C, the largest decrease in weight (moisture) occurred again in the perforated container, by 8.7 % (*Fig. 7*).

Fig. 8. Appearance of measured samples in perforated containers at the end of the measurement in April (left) and June (right) (Source: TGM WRI)

During the June measurement, fungi and animals (ants, slugs, flies) had a significant influence on the decomposition of matter, and thus also on the loss of weight compared to the April measurement. For comparison, *Fig. 8* shows the appearance of the measured sample at the end of the 14-day measurement in April (left) and June (right).

Based on the measured data on moisture loss, a uniform coefficient of 0.09 was determined, which will be included in the methodology "*Measurement of the amount and composition analysis of food waste*" as a correction factor for calculating the total amount of municipal food waste. After approval, its final version will be published on the project website [32] at the end of this year.

CONCLUSION

The issue of determining production and preventing the creation of food waste is currently a topic of project SS02030008 *"Centre of Environmental Research: Waste Management, Circular Economy and Environmental Security (CEVOOH)"*, within the framework of which, and in close cooperation with the MoE, we are preparing a methodology for measuring the weight of food waste. The analysis of approaches to solving the issue of BMW and food waste in selected EU countries shows us a number of different approaches that can be a suitable inspiration for dealing with the issue of prevention and effective management of this type of waste in the Czech Republic. The data and knowledge base of the food waste issue has currently been supplemented by the BMW moisture loss analysis, which is just under 10 % of the weight of the analysed waste and will be part of the newly prepared methodology.

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Development of land use and impact on water resources of hydrogeological unit 4232 Ústecká syncline in the Svitava river basin

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Keywords: land use — Ústecká Syncline in the Svitava river basin — groundwater

ABSTRACT

The research area of hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin (Ústecká synklinála v povodí Svitavy) is an important area of underground drinking water sources. These resources are of the highest quality and among the most abundant resources in the entire Czech Republic. The development of land use is closely connected with the development of settlements and industry (textile) in the research area, which in their importance far exceeded the borders of the region. Gradual development created pressure on natural resources, especially water; the demands on the quantity of service and drinking water increased, while the quality of water was affected by industrial and agricultural pollution. Despite the observed decrease in population in the last twenty to thirty years, we can see the expansion of settlements, mainly due to new construction on agricultural land, which is slightly compensated by the expansion of permanent grasslands and forests. With regard to current and future climate change, this increase, together with a slight increase in water bodies, can be considered as a positive phenomenon.

INTRODUCTION

Monitoring the development of landscape use is an important parameter in evaluating changes in the landscape and finding answers to changes observed in many natural and social processes. Changes in the landscape are generally influenced by geological and climatic processes and the impact of human activities [1, 2]. The landscape experienced great changes during the 19th and 20th centuries, across the whole of Europe. They were mainly related to the intensification of agriculture, development of urban and suburban zones, and industrial production; but, on the other hand, also to reforestation and grassing, especially from the second half of the 20th century [3]. In recent years, land use change has been associated with addressing the impacts of climate change. From the point of view of water management, there is pressure to implement semi-natural measures and to support water retention in the landscape, protection against floods and drought, etc. [4], thanks to which the representation of grass, forest, and water areas is increasing.

In the Czech lands, changes in landscape use are closely linked to the development of society, especially population migration, industrial development of a number of settlements and regions, and the subsequent increase in agricultural production [5]. In the last 200 years, arable land was first expanded at the expense of forests and grasslands; however, with the advent of modern agrotechnical practices, this trend gradually reversed [5–7]. In recent decades, the loss of arable land has been strongly influenced by the expansion of settlements into the countryside. This also applies to the selected research area of hydrogeological unit 4232 Ústecká Syncline in the Svitava basin. In the past, this territory was strongly influenced by the development of settlements, which experienced an industrial boom associated with the textile industry, especially at the turn of the 19th and 20th centuries. This was naturally connected with a large wave of migration; even small villages were formed into important centres with hundreds to thousands of inhabitants [8, 9].

However, the development of industry, population migration, and the growth of settlements resulted in direct changes in landscape structure and in a number of natural processes; in particular, there was a great pressure on water resources. Industry in general and textile industry in particular has always been closely connected with water (powering machinery, cleaning, leaching, etc.). The negative impact on water resources was manifested in the huge consumption of water and the deterioration of its quality. Simultaneously, the demands for drinking water increased due to the increase in population. All these changes had a visible response in the landscape, where its use gradually changed; for example, the loss of arable land for new construction, planting forests for the needs of harvesting construction timber and firewood, etc.

Many standard processes and changes in landscape use can be observed within the research area, which are similar to many other places. A specific feature of the area is an important water source in Březová nad Svitavou, which does not serve to supply the local population with drinking water, but was built for the city of Brno and its surroundings more than a hundred years ago [9]. Not just with regard to the future needs of the area, it was very important to perform an analysis of the area use and to uncover the "hidden laws" of the local landscape.

METHODOLOGY

Description of research area

The research area (*Fig. 1*) consists of hydrogeological unit 4232 Ústecká Syncline in the Svitava basin (hereinafter referred to as the HG unit). It is located on the border of the Pardubice and South Moravian regions in the vicinity of the town of Svitavy, at an altitude between 400 (southern part) and 650 metres above sea level (eastern and western edges). The area contains significant groundwater resources; these are mainly used for drinking purposes, not only

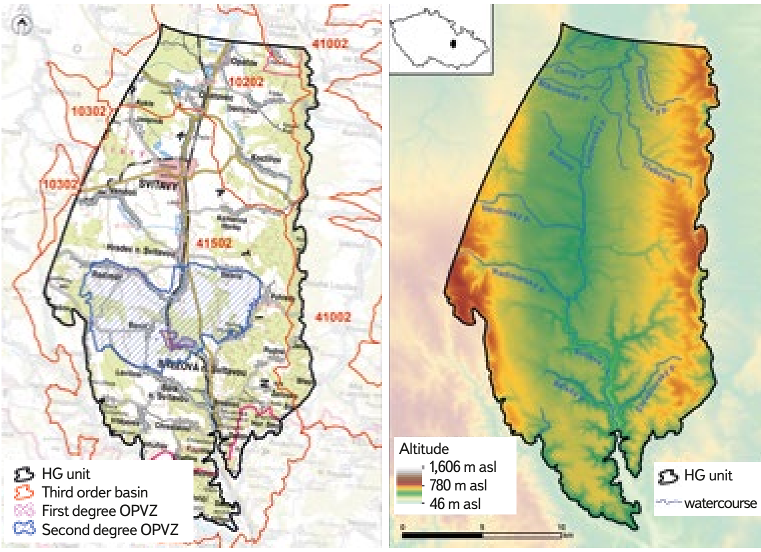

Fig. 1. Research area of hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin

for settlements within the HG unit, but groundwater from these sources plays a significant role in the supply of the city of Brno and other towns of the South Moravian region. For this reason, in the southern part of the HG unit, there are extensive protection zones for vulnerable water resource (WPZ) in Březová nad Svitavou, where two groundwater pumping systems operate (the so-called Březovský Water Supply systems I and II).

The HG unit area covers 358 km^2 and has a north-south orientation. It represents the eastern edge of the continuous occurrence of chalk sediments in the Czech Republic, and its structure is determined by the alternation of permeable hydrogeological aquifers (sandstones) and impermeable hydrogeological insulators (claystones) [10, 11]. The stratigraphic span of the HG unit is Cenomanian and Coniacian, and several aquifers are developed here as part of the progradational cycles: basal A (Peruc–Korycany Formation, insignificant for water management), B and C aquifers (the upper part of the Bílá hora and Jizera Formations with high transmissivity and intensive ground water circulation, both used for water management) and collector D (sandy delta) [10, 12].

The backbone watercourse of the area is the river Svitava, which originates in the northern part of the HG unit (the entire HG unit is the source of water for this river). In the northern part of the HG unit, north of the town of Svitava, there is a large area which is considered to be the source area of the Svitava river. In the recent dry years, however, the watercourse up to the town of Hradec nad Svitavou has been almost without water; sometimes they talk about the "spring of the Svitava river at the Hradec nad Svitavou WWTP", which cleans wastewater from the town of Svitavy. This also gives rise to the long-term problematic water quality in the river, especially in the section above Březová nad Svitavou. In the past, the main sources of water for the upper reaches of the Svitava were always the groundwater effluents in the area of today's water source in Březová nad Svitavou. The Svitava has several right-bank tributaries in its upper reaches, which are mostly fed by springs from the same groundwater layers. Left-hand tributaries are not developed in the upper section; surface water flows in the valleys only during torrential rains.

Methods used and input data

The land use development analysis was created using ArcMap 10.8.1 software (©ESRI). The input data were as follows: the maps of the second (1836–1852) and third (1876–1880) Austrian military mapping (AMM), topographic maps of Czechoslovakia (1953–1957), the Corine Land Cover database (©Copernicus Programme) for 1990–2018, and ZABAGED database (©ČÚZK) for 2023 (present).

In the first phase, land use maps were created for each period, which were then statistically analysed. Six basic categories of land use were established: *built-up area* (buildings and paved areas), *water body* (ponds and reservoirs), *forest* (all forest stands), *permanent grassland* (gardens, meadows, pastures, glades, and clearings), *agricultural area* (all arable land), and *other* (areas that could not be included in the previous categories, e.g. mining areas). Although this division does not have to correspond to the description of individual plots (e.g., in the property cadastre), it has been chosen with regard to the practical effects on the water regime of the landscape. For example, glades and clearings remain administratively forest land, although their actual function in the water regime is closer to meadows.

With the help of tools in ArcMAP 10.8.1 (©ESRI), it was possible to process and use in great detail the historical maps of Austrian military mapping (AMM) and topographical maps of Czechoslovakia for the selected research area. Nowadays, these maps are available in digital form (as WMS); however, land use maps had to be created manually (vectorization of historical maps; e.g. [13–15]). By combining the newly created datasets with the Corine Land Cover and ZABAGED databases, a 187-year long time series of the development of land use was created in nine time sections, resulting in a unique dataset with great temporal and spatial detail. This made it possible to analyse changes in landscape use at a resolution of up to a few metres.

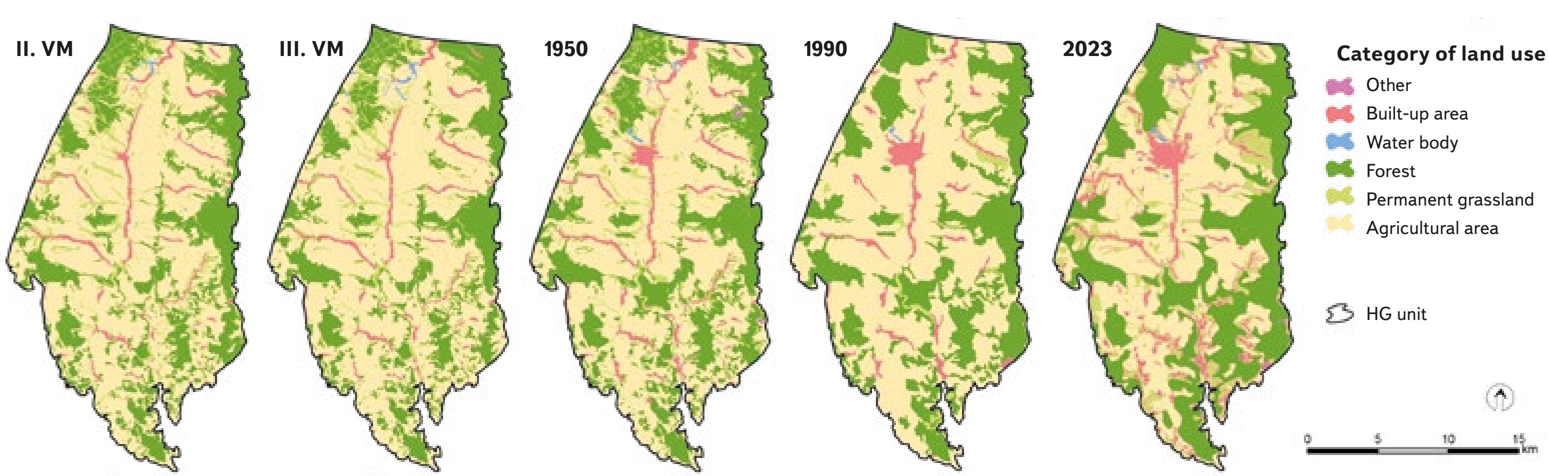

Fig. 2. Land use within hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin in five different time periods – II. AMM (1836–1852), III. AMM (1876–1880), 1950, 1990 and 2023

RESULTS AND DISCUSSION

Change in land use over the last 200 years

In general, we can say that over the years, *agricultural area* (40–60 %) has been most represented, which is mainly located in the central part of the HG unit; the land here is flatter with long, relatively gentle slopes (*Fig. 2*). The second important category is *forest* (30 %), or forest stands, which are most often found on the edges of the HG unit; the geomorphology here is more pronounced and unsuitable for agricultural management (*Fig. 2*). *Permanent grassland* and *built-up area* have a similar representation (5–10 %). *Built-up area* is strongly linked to the watercourses and their valleys; the settlements tend to be very long (even up to several kilometres), with an important centre of the town of Svitavy (*Fig. 2*). *Permanent grassland* are often around built-up areas because gardens and orchards are also included in this category. We also often come across grassland within the forests, which serve as clearings, glades, or cuttings during logging, allowing better movement for forest machinery (*Fig. 2*). There are a small number of *water bodies* here (maximum 0.3 %) and they are found mainly in the northern part of the HG unit, where the gentle terrain allowed the construction of ponds (*Fig. 2*). In the *other* category, mainly mining areas (stone mining) are included, essentially with a very limited occurrence in the southern part of the HG unit (*Fig. 2*).

Fig. 2 gives a summary of spatio-temporal changes in land use within the HG unit. There is a noticeable retreat of *agricultural area* in favour of *forest* and *built-up area*. *Forests* have seen a large increase since the mid-20th century, especially in the eastern part, where agricultural management gradually became disadvantageous due to relatively demanding natural conditions (steep terrain). In terms of settlements, the development of the town of Svitavy has been vital, mainly thanks to the industrial boom during the 20th century. In other municipalities, development is very erratic; in recent years, however, it has been associated with the boom in recreation and residential facilities for the town of Svitavy.

Development of the ratio of the individual land use categories is clearly visible in *Fig. 3*. The dominant share of *arable land*, over 50 % of the area, has been changing rapidly only in recent years; a large part of arable land is occupied by

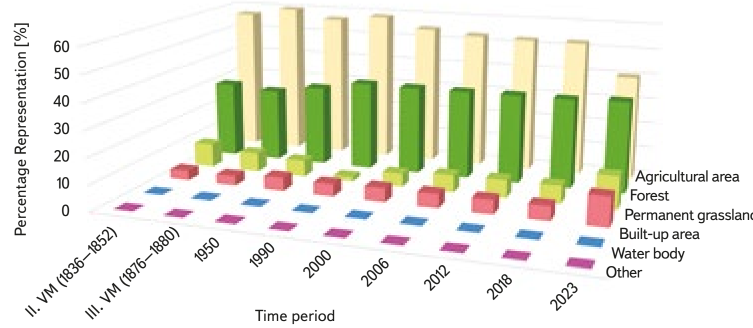

Fig. 3. Diagram of the development of individual categories of land use within the hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin from mid-19th century to the present

built-up area (increasing settlements mainly due to industrial zones) and *permanent grassland*, such as grassing valleys as, for example, anti-erosion and anti-flood measures. The relatively most stable category is *forest*, representing around 30 %; we can see a greater change in the second half of the 20th century, when afforestation took place at the expense of *permanent grassland*. The seemingly insignificant development of the categories *other* and *water body* can be better explained using *Tab. 1*. For the *other* category, we can see a clear increase in the 1950s (the development of mining due to the great need for building materials). The development of the representation of *water bodies* is interesting; in the second half of the 19th century, there was the development of small water reservoirs (ponds, water supply for industry), followed by a sharp decline at the end of the 20th century (often associated with the end of industrial activity). In the last 20 years, there has been a gradual growth due to recreation and an increase in the landscape retention capacity due to the drought intensification. The observed development trends in the monitored period correspond to changes across the Czech Republic [2, 7].

Tab. 1. Development of the share of individual categories of land use within the hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin from mid-19th century to the present

Category of land use [%]	Time period								
	II. VM (1836–1852)	III. VM (1876–1880)	1950	1990	2000	2006	2012	2018	2023
Other	0.0	0.0	0.2	0.0	0.1	0.1	0.1	0.1	0.1
Built-up area	3.7	3.8	5.2	4.8	5.4	5.4	5.5	5.5	11.3
Water body	0.1	0.3	0.2	0.1	0.2	0.2	0.2	0.2	0.3
Les Forest	30.0	28.5	31.3	34.6	34.3	34.4	34.6	34.6	35.3
Agricultural area	56.9	60.0	56.7	58.8	54.8	53.2	52.8	52.7	40.4
Permanent grassland	9.2	7.4	6.3	1.7	5.1	6.6	6.9	6.9	12.7

Impact on water resources

Changes in land use can have a strong impact on the state of natural resources, which are essential not only for human society. With regard to the research area, where an important source of drinking water is located within the Czech Republic, there is awareness of the possible impact of changes in the use of the landscape on local groundwater resources. The area is completely dependent on groundwater, as there are no major reservoirs or watercourses. On the other hand, the area represents a source area (e.g., The Svitava river) and all water flows from there. The favourable hydrogeological conditions here have enabled the creation of a number of natural groundwater exploitations. Among the most important sources in the area were the so-called Hladové, Petrovy and Sulkovy springs (*Fig. 4*), which today are tapped by both Březovský Water Supply systems, supplying water to the city of Brno [9, 16]. There are many other resources intended for local use in the area. A significant customer of groundwater is the Svitavy Group Waterworks (SGW; Skupinový vodovod Svitavy), which supplies the town of Svitavy and other municipalities in the vicinity. The location of the water sources is shown in *Fig. 4*. The spatial distribution is more or less uniform; however, natural springs are located mainly in the marginal areas of the area and in the southern part, where the terrain and hydrogeological conditions are more favourable.

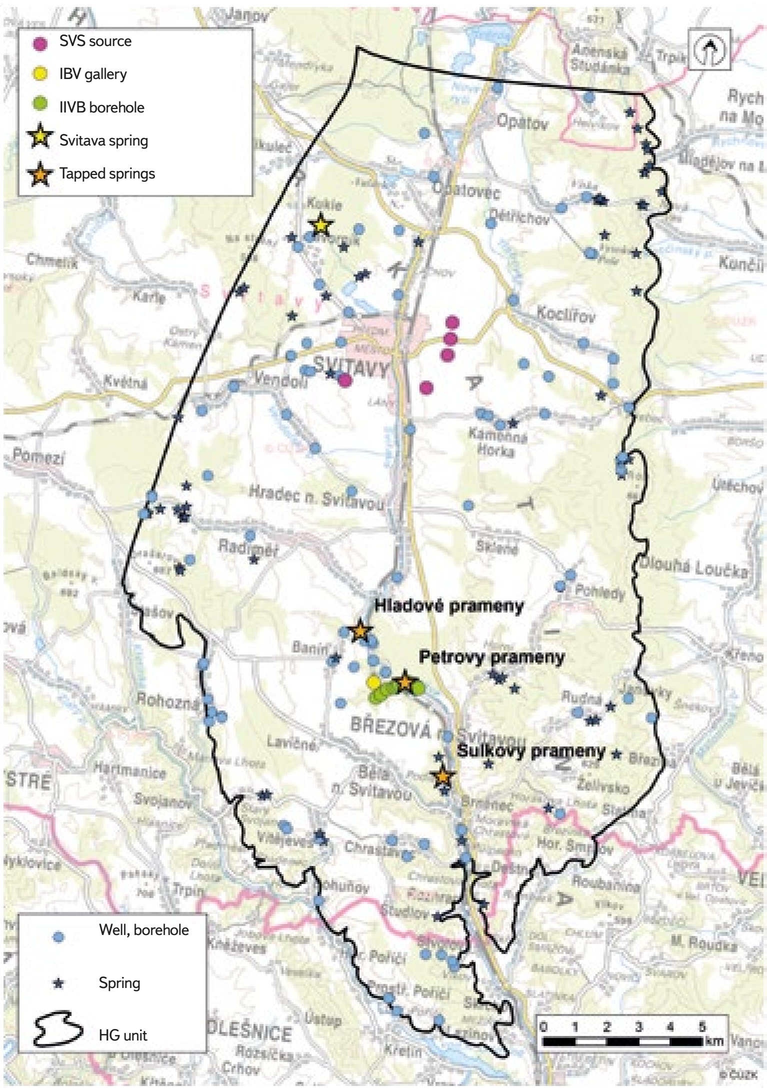

Fig. 4. Sources of groundwater within hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin (SVS – Skupinový vodovod Svitavy, IBWS – Březovský Water Supply system I, IIBWS –Březovský Water Supply system II)

There are also a number of smaller reservoirs in the area, which were built as a result of the development and modernization of human settlements. Due to the elevation of the terrain, these water reservoirs are mainly underground, located on the plateau above the settlement (*Fig. 5*). Their construction is closely connected with the development of settlements in the 20th century, when a number of municipal water supply systems were established [17]. The construction of an underground water reservoir not only represents a new visual element in the landscape, but also, together with its protection area, converts mostly originally arable land into built-up area with grassland.

Fig. 5. An example of a ground water reservoir near the town of Březová nad Svitavou (Photo: A. Létal, May 5, 2020)

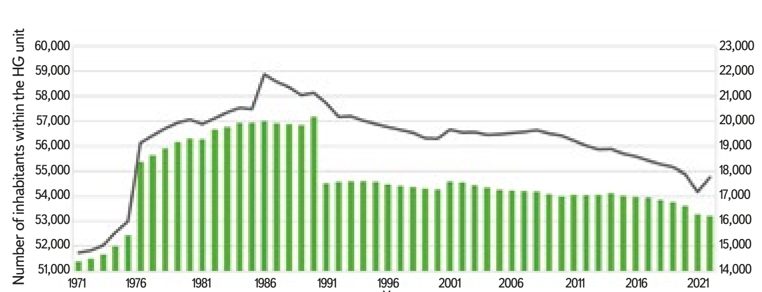

Fig. 6. Development of the number of inhabitants within hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin, 1971–2022 (Source: Czech Statistical Office)

Since the 19th century, the impact of changes in land use on water resources in the HG unit Ústecká Syncline in the Svitava river basin has been closely linked with the development of settlements, which had an impact on the entire structure of the landscape. As in many other places in the Svitava river basin, there was also the development of industry that used the local water resources. For example, the village of Radiměř had a unique system of up to 17 water mills operating from the 18th century, which were, among other things, used as fulling mills [8]. The centre of industry is the town of Svitavy, which has been an important settlement since the 16th century thanks to its location at the crossroads of trade routes. The town experienced great development from the second half of the 19th century thanks to the construction of the railway (1849). More than 100 textile factories were established in the town. Gradually, the structure of the industry changed; however, the importance of the town remained unchanged. The great development of Svitavy followed in the period after World War II. It was first affected by the displacement of the large German population and the subsequent influx of new residents from all over Czechoslovakia [18]. The town development can also be seen in *Fig. 2*. The textile industry and the increase in population had a great influence on the local water resources, especially during the 20th century. Since the end of the 20th century, this trend has stagnated or decreased as a result of the gradual decline of the population since the 1990s (*Fig. 6*), the general reduction of water consumption and, above all, the end of the activities of many large industrial enterprises in Svitavy, which also had a great impact on water quality in the Svitava river itself, see [9].

A specific feature of the entire area is the water source in Březová nad Svitavou, which has already been mentioned several times. It drains a relatively large part of the local groundwater supply to Brno (about 60 km away) and other settlements. It was built in two phases (1911–1913 and 1970–1975) for the needs of a rapidly growing city [9, 16]. The influence of this water source was evident in the Svitava river, where the flow decreased significantly while the water quality deteriorated, which was caused by the lower flows and, at the same time, intensive industrial activity in Svitavy [19]. The water source itself also had an effect on the local use of the landscape; the residents were resettled and the village of Muzlov was demolished, including the subsequent afforestation or grassing of the entire first degree water protection zone [9].

In recent decades, there has been a growth of the landscape phenomenon of increasing the number of areas with permanent grassland, small water reservoirs, wetlands, etc. This trend is linked to efforts to improve the landscape's retention capacity, strengthen its overall resilience to the negative effects of climate change, and promote its diversity with respect to ecosystem services and biodiversity [20, 21]. These changes in the landscape structure are associated with the implementation of semi-natural measures [4]. With regard to the mostly positive response to these measures in the landscape and their effectiveness (as reported by, for example, Dzuráková [22] and Beran [23]), they will be increasing, and therefore there will also be a further increase in the categories of permanent grassland, water body, and forest, mostly at the expense of agricultural areas, where these measures are most often applied.

CONCLUSION

Changes in the use of the landscape always have an effect on the natural conditions in an area, whether positive or negative. As part of the research area of hydrogeological unit 4232 Ústecká Syncline in the Svitava river basin, there have been gradual changes in the landscape composition, which are mainly conditioned here by the development of society, settlements, and industry. Despite the fact that during the last 200 years there has been an increase in the representation of forests and permanent grasslands, which could be described as a positive change, there were also negative impacts associated mainly with the development of industry (impact on the quality of surface water) and the growth of settlements, which generally exerted pressure on local water resources. A specific feature of the area is an important source of groundwater in Březová nad Svitavou, which has been draining a huge amount of water far outside the research area for more than 100 years. With regard to climate change, which also manifests itself within the research area, it is important to monitor changes in the landscape and the future development of the area and to support landscape changes with an expected positive impact, such as increasing the retention capacity of the landscape by building smaller reservoirs, wetlands, forest stands, etc.

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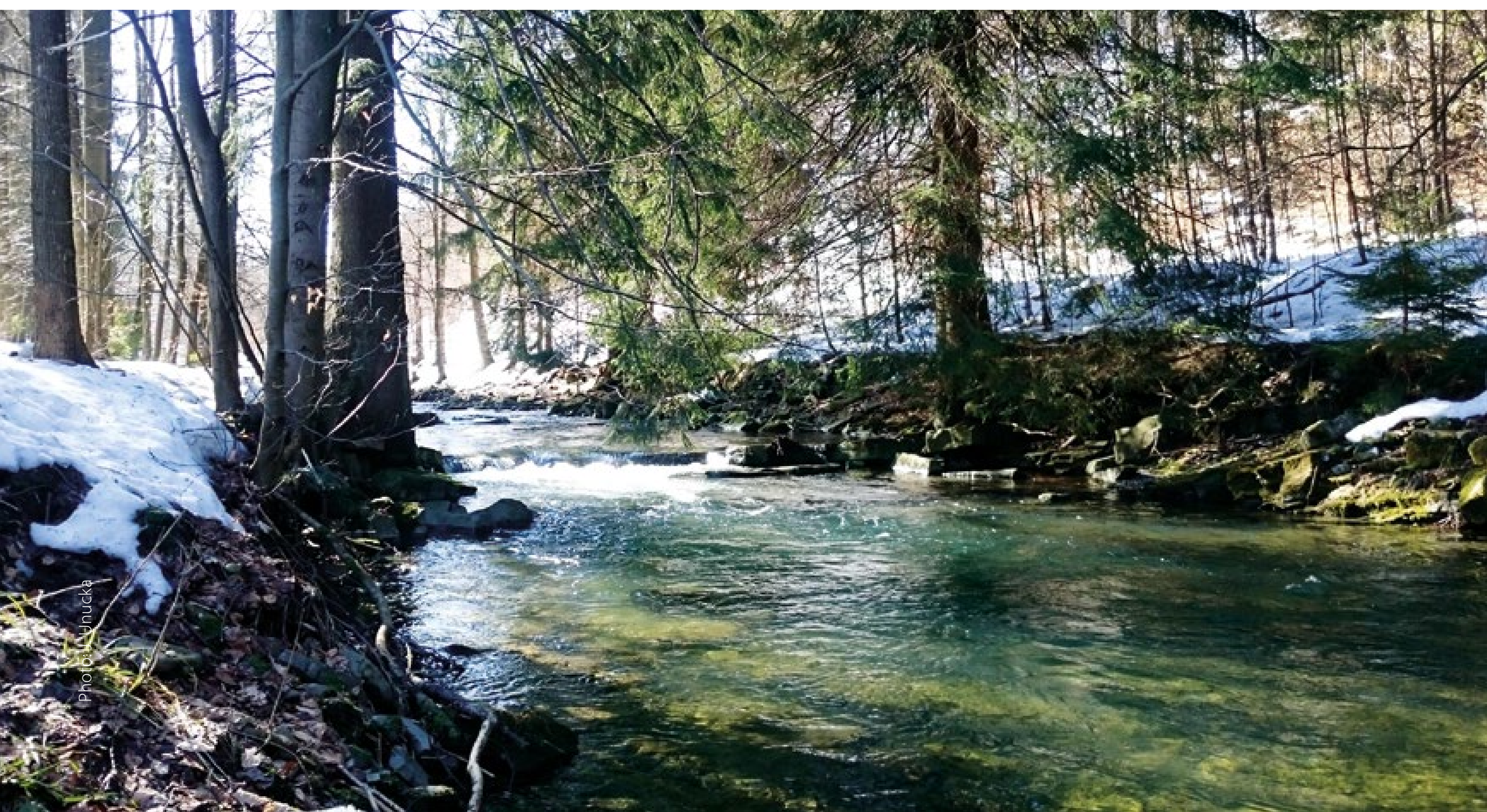

Use of effect-based methods to assess surface water status

MARTIN HORA, ALENA KRISTOVÁ, PŘEMYSL SOLDÁN

Keywords: effect based methods — surface waters — ecotoxicology

ABSTRACT

This article deals with the use of effect-based methods for the qualitative assessment of the state of surface waters in the context of Directive 2000/60/EC establishing the framework for Community activity in the field of water policy and the upcoming amendment to Directive 2008/105/EC on environmental quality standards. The implemented monitoring of priority substances and specific pollutants is not able to capture all sources of pollution that negatively affect surface water quality. Likewise, current practice does not allow a comprehensive assessment of mixtures, including emergent pollutants, metabolites, and transformation products of substances on water quality. Effect-based methods are a suitable tool for ecotoxicological evaluation of pollution, which considers all substances contained in the sample and possible effects of mixtures (synergistic effects). They thus provide important additional information for the results of the assessment of the state of surface water bodies.

INTRODUCTION

The Water Framework Directive 2000/60/EC requires the Member States of the European Union (EU) to adopt an integrated approach to the monitoring and assessment of surface water quality. In the Czech Republic, monitoring takes place in accordance with the requirements of Decree 98/2011 [1] as amended by Section 21 of the Water Act [2] and environmental quality standards throughout the EU. However, for technical and economic reasons, the current monitoring of the chemical state of water does not allow analysis, detection, and quantification of all substances present in the aquatic environment [3, 4]. It is primarily focused on monitoring selected regulated chemical substances – priority substances and other pollutants which are known to pose a danger to the aquatic environment. However, this information does not tell us anything about their actual cumulative effects in the aquatic environment. In addition, it is necessary to include the action of so-called emergent micropollutants in the monitoring. These include medicines and cosmetics, biocides, polar pesticides, endocrine disruptors, their metabolites, and transformation products. In addition, substances present in the aquatic environment create mixtures whose final effect cannot be predicted on the basis of chemical analysis alone.

The main goal of the project "*Using effect-based methods to assess the status of surface waters in the context of the Water Framework Directive*" is to create a methodology for the assessment of water pollution using effect-based methods (EBM), the use of which would be appropriate to include in the Water Framework Directive 2000/60/EC (WFD) [5]. This type of monitoring is a useful ecotoxicological tool for the assessment of water pollution, serving as a screening method, allowing to precisely target other types of monitoring and, subsequently, find the origin of the pollution and set measures to improve water status. This issue is dealt with in detail, for example, by US EPA documents [6–8]. Simultaneously, an amendment to Directive 2008/105/EC is currently being discussed at the Member States level, which in Article 8a introduces a new obligation to monitor the presence of estrogenic substances in water bodies using EBM for a period of two years; in case of positive findings, the following hormones will be monitored by conventional analytical methods: 7-beta-estradiol (E2), estrone (E1), and alpha-ethinyl-estradiol (EE2).

EBMs are analytical methods using whole organism responses (*in vivo*) or cellular responses (*in vitro*) to detect and quantify the effects of different groups of chemicals and to determine relevant toxicological endpoints [4]. Incorporation of these methods into current monitoring would therefore allow evaluation of the effects of complex pollutant mixtures occurring in the environment according to the mechanism of their action [5, 7–9].

EBM can help prioritize problematic groups of substances; this can be used for designing targeted measures to reduce their introduction and to improve water quality. Another important aspect of their use is the potential to reduce the burden associated with monitoring an ever-growing list of priority substances and pollutants. EBMs are suitable for linking the monitoring of the chemical and ecological status of the aquatic environment and can help determine the causes of the unsatisfactory ecological water status, as well as to identify other substances that may be a threat to both aquatic ecosystems and human health. Using EBM enables a cost-effective risk analysis where the absence of an effect implies the absence of toxicological risk.

The methods used were chosen with a view to covering different mechanisms of action of toxic substances based on the required sensitivity. The basic document was the EU technical report [11] and other sources [10, 12]. Considering the small volume of the sample after the necessary pretreatment, ecotoxicity tests were chosen on representatives of two trophic layers of aquatic ecosystems – decomposers (bacteria *Aliivibrio fischeri*), and primary producers (green algae *Raphidocelis subcapitata*). Mutagenicity was determined using the Ames fluctuation test [12, 14, 15]. In recent years, water quality testing has been focused on estrogens and substances with an estrogenic effect. The YES test (yeast estrogen screen) [16, 17] was used to determine the level of estrogens and estrogenic substances recommended for monitoring at the EU level [12].

METHODOLOGY

Selection of profiles and sampling plan

Eleven locations in three river basins (Odra, Morava, and Labe basins) were selected for the assessment of surface water status using EBM, based on CHMI data and consultations with the Povodí state enterprises. Nine locations show long-term poor water quality, which in most cases is caused by exceeding limit of phosphorus and nitrogen concentrations, but also by an increased occurrence of some priority substances and other pollutants and metals (according to Government Regulation No. 401/2015 Coll. [17]). Two locations were selected as the reference ones with reported long-term good water quality. The selected profiles are listed in *Tab. 1*; the site map is shown in *Fig. 1*.

Tab. 1. Water profiles overview

Odra basin	Morava basin	Labe basin
CHMI_3585 Hvozdnice – ústí	CHMI_3670 Bečva – Troubky	CHMI_0101 Labe – Valy
CHMI_1154 Lučina – Slezská Ostrava	CHMI_1171 Bečva – Choryně	CHMI_1026 Orlice – Nepasice
CHMI_1163 Odra – Bohumín	BPPVB009 Vsetínská Bečva – river mouth*	
CHMI_3791 Olše – ústí		
CHMI_1152 Ostravice – Ostrava		
CHMI_1141 Opava – Krnov*		

*Reference profiles with good water quality

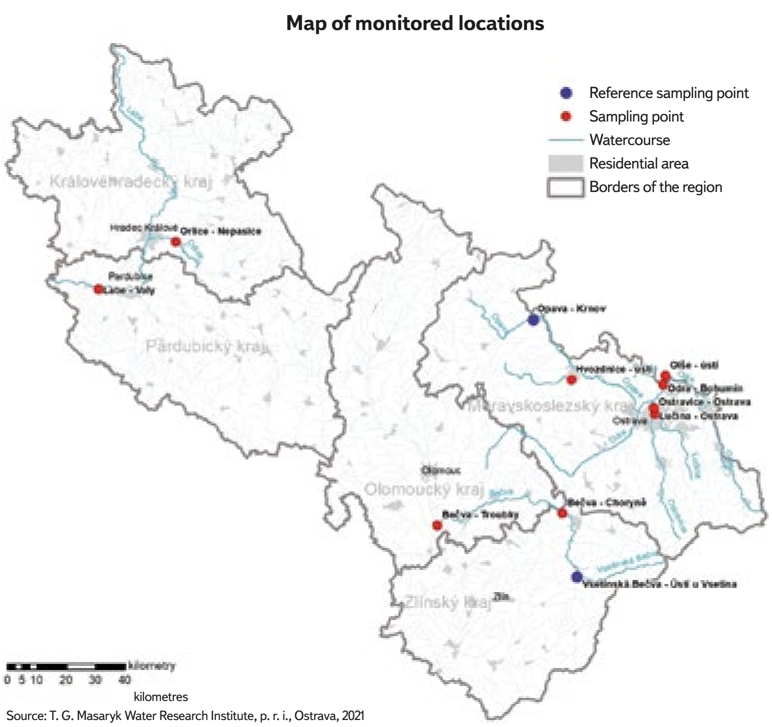

Fig. 1. Map of monitored locations

A total of six sampling campaigns took place in 2021 and 2022 (*Tab. 2*).

Tab. 2. Overview of abstraction dates on selected monitored profiles

Profile	Abstractions 2021		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – ústí	30. 06. 2021	31. 08. 2021	05. 10. 2021
Opava – Krnov	15. 07. 2021	19. 08. 2021	07. 10. 2021
Lučina – Slezská Ostrava	29. 07. 2021	31. 08. 2021	14. 10. 2021
Ostravice – Ostrava	01. 07. 2021	31. 08. 2021	14. 10. 2021
Olše – ústí	07. 07. 2021	04. 08. 2021	06. 10. 2021
Odra – Bohumín	07. 07. 2021	04. 08. 2021	06. 10. 2021
Bečva – Choryně	21. 07. 2021	24. 08. 2021	25. 10. 2021
Vsetínská Bečva – ústí	22. 07. 2021	25. 08. 2021	26. 10. 2021
Bečva – Troubky	21. 07. 2021	24. 08. 2021	25. 10. 2021
Orlice – Nepasice	29. 06. 2021	x	04. 10. 2021
Labe – Valy	29. 06. 2021	x	04. 10. 2021
Profile	**Abstractions 2022**		
	1st campaign	**2nd campaign**	**3rd campaign**
Hvozdnice – ústí	04. 04. 2022	27. 06. 2022	25. 10. 2022
Opava – Krnov	13. 04. 2022	18. 07. 2022	13. 10. 2022
Lučina – Slezská Ostrava	29. 03. 2022	29. 06. 2022	03. 10. 2022
Ostravice – Ostrava	29. 03. 2022	29. 06. 2022	03. 10. 2022
Olše – ústí	06. 04. 2022	13. 07. 2022	05. 10. 2022
Odra – Bohumín	06. 04. 2022	13. 07. 2022	05. 10. 2022
Bečva – Choryně	23. 03. 2022	26. 07. 2022	24. 10. 2022
Vsetínská Bečva – ústí	25. 04. 2022	25. 07. 2022	24. 10. 2022
Bečva – Troubky	25. 04. 2022	26. 07. 2022	24. 10. 2022
Orlice – Nepasice	05. 04. 2022	11. 07. 2022	04. 10. 2022
Labe – Valy	05. 04. 2022	08. 08. 2022*	04. 10. 2022

x sample not taken
*Labe – Valy, invalidation of July sample collection on 11/07/2022, sampling repeated on 8/08/2022

METHOD USED

Pretreatment of samples

Pretreatment of samples consists of concentrating the pollution contained in them. This procedure is chosen on the basis of the assumption that an increase in the concentration of active substances will make it possible to model their possible chronic effect within a significantly shorter exposure time, i.e., using acute toxicity tests (the effect is influenced by the indirect dependence of the concentration on exposure time).

Concentration of the collected samples was carried out according to TNV 75 7231 [18]. XAD resins were added to 20 litres of surface water sample and the sample was mixed for 24 hours. The adsorbed substances were then washed with solvent and transferred to an aqueous 1000x concentrated sample. It was subsequently used for evaluation using selected effect-based methods:

- Toxicity test with decomposers: Microtox test with the luminescent bacterium *Aliivibrio fisheri* according to ČSN EN ISO 11348 standard [15].
- Toxicity test with producers: miniaturized green algae growth inhibition test according to ČSN EN ISO 8692 standard [16].
- Endocrine disruption – evaluation of estrogenicity using a commercial kit using the yeast *Saccharomyces cerevisiae* (S-YESMD New Diagnostic).
- Genotoxicity – determination of direct mutagenicity using the Ames test with a bacterial culture of *Salmonella typhimurium* (strains TA 98 and TA 100) according to ISO 11350 : 2012 standard [21].

When performing tests, increased toxicity of blank samples was noted in some cases. Since the influence of the solvent was ruled out, we assumed the influence of residual toxicity after conditioning of the polymer resins (XAD resins). XAD resins are commercially supplied and stored wet in containers with added sodium chloride and sodium carbonate to prevent unwanted microbial growth. In addition, other undesirable substances can be adsorbed onto the resins from the production process, which can negatively affect the results of the ecotoxicity tests themselves. The original procedure of cleaning with methanol and subsequent rinsing with demineralized water was adjusted based on the data obtained from the research. The resins were cleaned and conditioned in Soxhlet extractors for 8 hours with methanol, followed by 8 hours with acetone [22]. These are solvents that are used in the subsequent steps of testing even during the extraction of sorbed substances and are also recommended by manufacturers of XAD resins (e.g. Supelco, Sigma Aldrich).

In addition to the change in the conditioning of the XAD resins, there was also a change compared to TNV 75 7231 in the extraction method. The mentioned standard recommends acetone for extraction. Methanol was added as a second reagent, which is a more polar solvent compared to acetone and is suitable, for example, for the extraction of a wide range of pesticides and pharmaceuticals, where the extracted substances should be expanded by the mentioned substances with a higher polarity. Changes to the extraction procedures included mixing the resins with the sorbates in the column with methanol for 30 minutes. The methanol extract was poured from the columns into prepared containers. Acetone was then gradually added to the resins in the columns, in two subsequent steps, for a period of 2× 15 minutes. The first acetone extract also contained a small amount of methanol from the first extraction step; therefore, after 15 minutes the sorbed substances on the resins were extracted again with pure acetone. The final acetone extract was created by combining the two acetone extracts.

The resulting methanol and acetone extracts were first concentrated to a volume of 5 ml on a Heidolph vacuum rotary evaporator (water bath temperature of 50 °C, pressure of 300 mbar for the methanol extract and 550 mbar for the acetone extract) [22–25]. The extracts were extended with nitrogen to a final volume of 100 µl. The concentrated acetone and methanol extracts were filled with demineralized water to a volume of 10 ml. In the last step, these samples were mixed together and a 1,000× concentrated aqueous sample with a volume of 20 ml was created for effect-based analyses.

Determination of estrogens

Determination of selected estrogens (E2 – 17β-estradiol, EE2 – 17α ethinyl estradiol, E1 – estrone) by LC/MS method was carried out on 15 selected samples of concentrated surface water from 2021 on a liquid chromatograph in the laboratories of the Department of Hydrochemistry, TGM WRI in Prague.

Toxicity test – luminescence test with *A. fischeri*

Determination of the inhibitory effect of the samples on the light emission of the marine luminescent bacteria *Aliivibrio fischeri* was carried out according to ČSN EN ISO 11348-2 standard. These are marine aerobic, heterotrophic, gram-negative bacteria capable of bioluminescence. Light emission is produced by the catalytic effects of the enzyme luciferase on the low molecular weight substrate luciferin. Due to the toxic substances contained in the tested sample, the luminescence emitted by these bacteria decreases. This reduced value is recorded and compared to the control test (*Figs. 2* and *3*). The results of the analyses of the bioluminescence test are shown in EC_{50} values (ml/l) in *Tab. 2*. These values represent the concentration at which there was a 50 % decrease in luminescence compared to the control test.

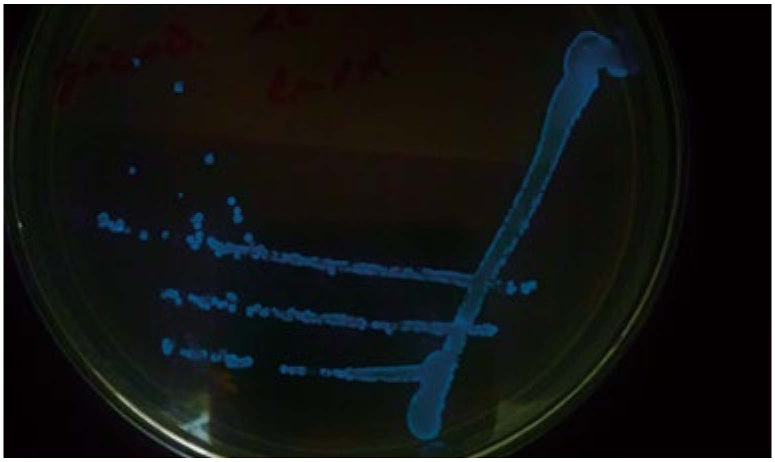

Fig. 2. Example of luminescent bacteria *A. fischeri* cultured on a Petri dish

Fig. 3. Measurement of luminescence intensity changes during the test

Toxicity test – miniaturized algae test with *R. subcapitata*

The freshwater green algae growth inhibition test is based on ČSN EN ISO 8692 standard (*Fig. 4*). Due to the limited number of concentrated samples obtained, a miniaturized algae test method was used. The miniaturized version does not take place in Erlenmeyer flasks, but in 96-well microtiter plates. The basic solutions and test conditions remain identical to the already mentioned standard. The essence of the test consists of cultivating the algal culture *R. subcapitata* in samples with the addition of a nutrient medium necessary for the growth of algae. Cultivation takes place in a test room with a constant temperature of 22 °C, with a light intensity of over 6,000 lx. After 72 h, the specific growth rate of the examined samples is compared with the control sample. The resulting values of the analysed samples are expressed in % of inhibition (or stimulation) of algae growth compared to the control sample.

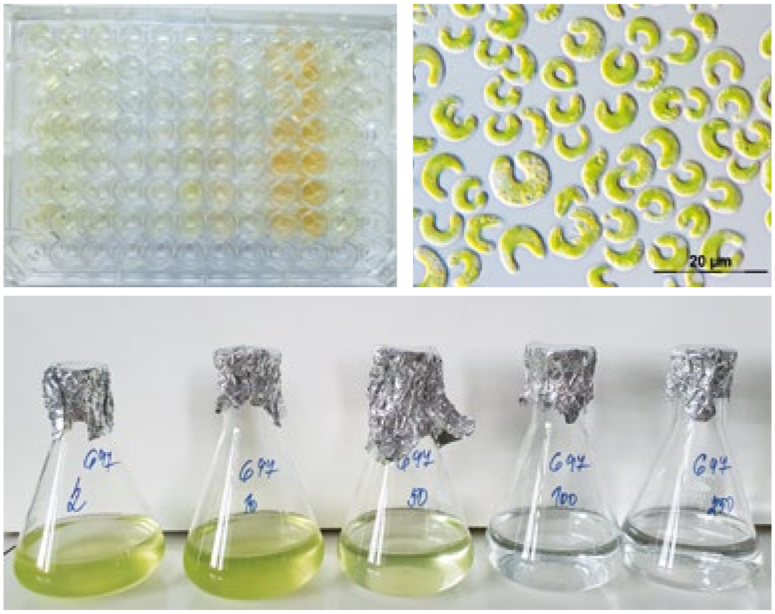

Fig. 4. Example of miniaturized algal test (left); microalgae *R. subcapitata* (right); the standard version of the algal test running in Erlenmeyer flasks (bottom).

Genotoxicity test – Ames fluctuation test

The Ames fluctuation test (ISO 11350) was used to detect the presence of substances with a mutagenic effect. Using two genetically modified bacterial strains of *Salmonella enterica* subsp. *enterica* serotype *Typhimurium* TA 98 and TA 100, this test monitors the occurrence of direct and indirect mutagens in the aquatic environment. By using both mentioned strains (TA 98 and TA 100), it is possible to detect substances in the samples that induce point mutations (base substitutions and displacement mutations) in genes encoding enzymes that participate in the biosynthesis of the amino acid histidine. A two-fold increase in the number of revertants is considered significant (*Fig. 5*).

In the Ames test, evaluation of the cytotoxic effects of the samples on Salmonella bacterial strains is also recommended, based on the evaluation of the growth rate of bacterial strains compared to control samples. Detection of cytotoxicity is recommended by ISO 11350 standard only for the Salmonella strain TA 98. With the strain TA 100, the results may be distorted due to lower growth rate. Due to significant staining of some analysed samples which distorted the cytotoxicity evaluation, it will be necessary to optimize the evaluation.

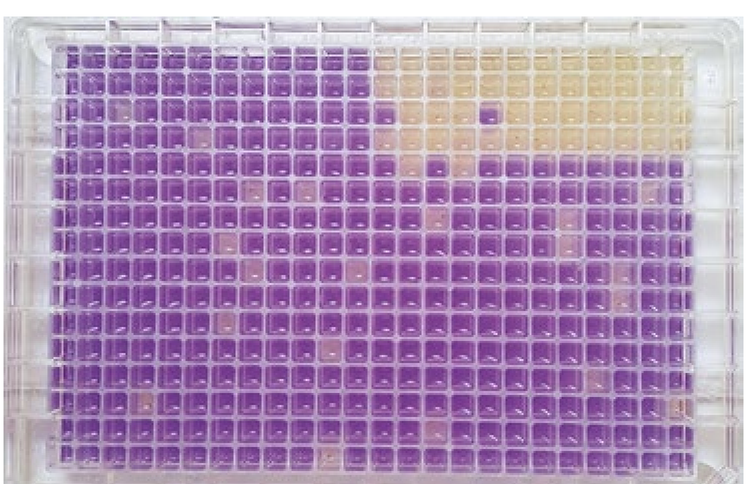

Fig. 5. Ames fluctuation test on a microtiter plate

Ames test with metabolic activation (S9+)

In 2022, samples were also tested in a variant of the Ames test with metabolic activation S9+, monitoring indirect mutagens which require metabolic activation by liver enzymes in order to manifest their mutagenic effect. In this variant, samples with a concentration of 500 ml/l were tested.

Test to determine estrogen potential – Yeast estrogen test (YES test)

The YES test method is aimed at determining the estrogenic potential of aqueous samples. The procedure is based on ISO 19040-1 : 2018 standard [26]. This colorimetric YES test uses recombinant *Saccharomyces cerevisiae* yeast cells genetically engineered to express the human estrogen receptor alpha (hER). Depending on the presence of estrogenic substances in the sample, the colour of the indicator (CPRG) changes as the substance binds to the estrogen receptor. This initiates the expression of the reporter gene and the synthesis of β-galactosidase, which is released by the cell into the medium, in which it catalyses the conversion of the yellow CPRG substrate to red (*Fig. 6*). The intensity of the red colour is related to the level of estrogenic activity of the sample and is evaluated spectrophotometrically at OD_{570} nm. The measured optical density (OD) is directly correlated with the amount of β-galactosidase released, and thus with the activity of the test substance that has bound to the receptor.

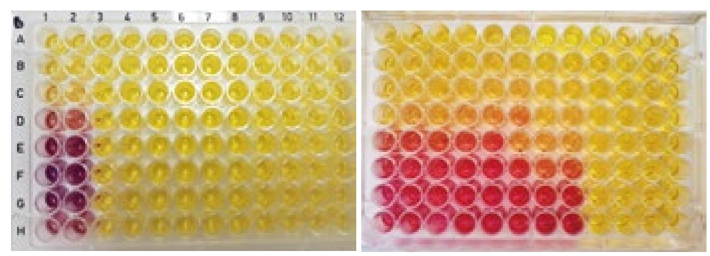

Fig. 6. YES test

RESULTS

Determination of estrogens

Measurements were carried out on samples collected during three campaigns in 2021 in selected profiles. None of the estrogens could be determined in the samples as their values were below the detection limit.

Toxicity test – luminescence test with *A. fischeri*

From the results in *Tab. 3a* and *3b*, it can be seen that the lowest EC_{50} values were recorded in both years 2021 and 2022 during the first sampling campaign, where EC_{50} values were in a range of 15–119 ml/l. Samples collected in the second sampling campaign had EC_{50} values in a range of 40–378 ml/l, with values in 2021 being slightly higher than in 2022. In the third sampling campaign, the EC_{50} values ranged from 43 to 434 ml/l, while the values in 2021 were again slightly higher compared to 2022.

In general, we can say that almost all samples during the first sampling campaign had a greater effect on luminescence inhibition compared to samples from the second and third sampling campaigns. None of the EC_{50} values found was lower than 10 ml/l, i.e., the value indicating significant toxicity of the samples.

The EC_{50} values found for samples from some profiles in individual campaigns differed significantly. For example, the EC_{50} value of the sample from the Opava – Krnov profile in 2022 from the first campaign was among the lowest, with an EC_{50} value of 18 ml/l. In contrast, samples taken from this profile during the summer and autumn campaigns were among the least toxic. In contrast, the smallest difference in EC_{50} values was found for samples taken in 2022 on the Labe – Valy profile. Samples from this profile showed almost identical EC_{50} values in all three campaigns.

Tab. 3a. Results of the luminescent test with A. fischeri, EC_{50} values after 30 min in [ml/l] (2021)

Profile	EC_{50} [ml/l]		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – river mouth	25 CHT	115	125
Opava – Krnov	63 CHT	91	279
Lučina – Slezská Ostrava	119	59 CHT	88
Ostravice – Ostrava	23 CHT	84	119
Olše – river mouth	51 CHT	40 CHT	60 CHT
Odra – Bohumín	59 CHT	48 CHT	86
Bečva – Choryně	40 CHT	108	306
Vsetínská Bečva – river mouth	55 CHT	378	434
Bečva – Troubky	42 CHT	263	344
Orlice – Nepasice	17 CHT	x	73
Labe – Valy	17 CHT	x	64

x sample not taken
CHT – chronic toxicity

Tab. 3b. Results of the luminescent test with A. fischeri, EC_{50} values after 30 min in [ml/l] (2022)

Profile	$EC5_{50}$ [ml/l]		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – river mouth	24 CHT	144	55 CHT
Opava – Krnov	18 CHT	160	224
Lučina – Slezská Ostrava	52 CHT	34 CHT	72
Ostravice – Ostrava	32 CHT	61 CHT	60 CHT
Olše – river mouth	15 CHT	114	183
Odra – Bohumín	27 CHT	154	137
Bečva – Choryně	*	88	50 CHT
Vsetínská Bečva – river mouth	54 CHT	341	43 CHT
Bečva – Troubky	15 CHT	96	91
Orlice – Nepasice	64	82	162
Labe – Valy	65	71	70

* sample processed differently from other samples (different method of resin conditioning). EC50 value was 200 ml/l.
CHT – chronic toxicity

Toxicity test – miniaturized algae test with *R. subcapitata*

Tab. 4a and *4b* show the results of the analysed surface water samples collected in 2021 and 2022. It is clear that a four-fold dilution (c 250 ml/l) of the samples in some cases caused 100 % inhibition of algae growth. The toxicity gradually decreased with further dilution. At a 100-fold dilution (i.e. a concentration of 10 ml/l) the samples had a toxic effect only exceptionally.

In the first sampling campaign of 2021, the sample in the Hvozdnice – river mouth profile showed increased toxicity; in the second sampling campaign, it was the sample in the Odra – Bohumín profile. In the third sampling campaign, no significant toxic effect of any of the samples was recorded. Similarly, in the first sampling campaign of 2022, only the sample from the Odra – Bohumín profile showed increased toxicity in the above-mentioned concentration. In the second sampling campaign, high toxicity was detected in this concentration in a sample from the Bečva – Troubky profile. In the third sampling campaign, no significant toxic effect of any of the samples was recorded. In the summer and autumn campaign, algae growth was stimulated in some of the examined samples due to the substances contained in them.

Although the algae inhibition effect appears to be significant in some concentrations, it should be noted that 1,000× concentrated surface water samples were analysed. These samples were subsequently diluted in the tests in order to find out which concentrations still have a significant inhibitory effect on algal growth and which, in contrast, have minimal effect.

Tab. 4a. Algae test results with R. subcapitata, EC_{50} in [ml/l] (2021)

Results 2021 – algae			
Profile	EC_{50} [ml/l]		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – river mouth	30.33 HU	50.1 HU	c_{500} 28.83 %
Opava – Krnov	c_{500} 24.68 %	204.3	c_{500} 43.25 %
Lučina – Slezská Ostrava	c_{500} 20.77 %	94.8	c_{500} 1.66 %
Ostravice – Ostrava	470.1	199.2	c_{500} 3.33 %
Olše – river mouth	186.9	49.0 HU	306.9
Odra – Bohumín	132.1	26.5 HU	163.0
Bečva – Choryně	144.9	88.6	478.2
Vsetínská Bečva – river mouth	c_{500} 36.48 %	c_{500} 14.77 %	c_{500} 11.59 %
Bečva – Troubky	113.6	469.2	c_{500} 19.53 %
Orlice – Nepasice	371.4	x	234.4
Labe – Valy	69.3	x	116.9

x sample not taken
HE – herbicidal effect
C_{500} – effect at a concentration of 500 ml/l

Tab. 4b. Algae test results with R. subcapitata, EC_{50} in [ml/l] (2022)

Results 2022 – algae			
Profile	**EC_{50} [ml/l]**		
	1st campaign	**2nd campaign**	**3rd campaign**
Hvozdnice – river mouth	76.2	28.5 HU	101.8
Opava – Krnov	c_{500} 46.8 %	c_{500} 10.3 %	c_{500} 29.86 %
Lučina – Slezská Ostrava	108.1	54.3 HU	174.0
Ostravice – Ostrava	c_{500} 48.08 %	216.9	111.5
Olše – river mouth	104.3	184.6	418.4
Odra – Bohumín	31.9 HU	123.7	322.4
Bečva – Choryně	c_{500} 11.6 %	235.4	192.8
Vsetínská Bečva – river mouth	242.3	c_{500} 48.42 %	468.3
Bečva – Troubky	20.3 HU	57.6 HU	161.1
Orlice – Nepasice	c_{500} 33.35 %	443.2	c_{500} 26.53 %
Labe – Valy	157.8	116.6	107.7

HE – herbicidal effect

Tab. 5. Results of the Ames fluctuation test in the variant without metabolic activation S9-

Ames test variant S9-						
Profile	**1st campaign**		**2nd campaign**		**3rd campaign**	
	TA98	**TA100**	**TA98**	**TA100**	**TA98**	**TA100**
Hvozdnice – river mouth	+	-	+	-	+	-
Opava – Krnov	+	+	-	-	-	-
Lučina – Slezská Ostrava	-	+	+	-	-	-
Ostravice – Ostrava	+	-	-	+	-	-
Olše – river mouth	-	-	+	+	+	-
Odra – Bohumín	-	-	+	-	-	-
Bečva – Choryně	-	-	-	-	-	-
Vsetínská Bečva – river mouth	-	-	-	-	-	-
Bečva – Troubky	-	-	-	-	-	-
Orlice – Nepasice	-	-	x	x	-	-
Labe – Valy	-	-	x	x	+	-

\+ there was a significant increase in the number of revertants in the samples (2021)
– there was no significant increase in the number of revertants in the samples (2021)
x sample not taken

Tab. 6. Comparison of Ames fluctuation test results in the variant without metabolic activation S9- and the variant with metabolic activation S9+

Ames test variants S9- and S9+						
Profile	**1st campaign**		**2nd campaign**		**3rd campaign**	
	S9-	**S9+**	**S9-**	**S9+**	**S9-**	**S9+**
Hvozdnice – river mouth	-	-	-	-	-	-
Opava – Krnov	-	-	-	-	-	-
Lučina – Slezská Ostrava	+	-	-	-	-	-
Ostravice – Ostrava	-	-	-	-	-	-
Olše – river mouth	-	-	-	-	+	+
Odra – Bohumín	-	-	+	-	+	-
Bečva – Choryně	-	+	+	-	-	-
Vsetínská Bečva – river mouth	-	-	-	-	+	+
Bečva – Troubky	-	-	+	-	+	-
Orlice – Nepasice	-	-	-	-	+	-
Labe – Valy	+	+	+	+	-	-

\+ there was a significant increase in the number of revertants in the samples (2022)
– there was no significant increase in the number of revertants in the samples (2022)

Genotoxicity test – Ames fluctuation test with metabolic activation (S9+) and without metabolic activation (S9-)

In 2021, the results of the Ames fluctuation test were obtained in the variant without metabolic activation of S9- (*Tab. 5*), where only direct mutagenic substances were monitored. In the first campaign, mutagenic substances were detected on the profiles of Hvozdnice – river mouth, Opava – Krnov, Lučina – Slezská Ostrava, and Ostravice – Ostrava. In the summer campaign, they were detected in the profiles Hvozdnice – river mouth, Lučina – Slezská Ostrava, Ostravice – Ostrava, Olše – river mouth, and Odra – Bohumín. In the autumn campaign, the Hvozdnice – river mouth, Olše – river mouth, and Labe – Valy profiles tested positive.

Tab. 6 shows a comparison of the result of the Ames fluctuation test in the variant without metabolic activation S9- and the variant with metabolic activation S9+ in surface water samples collected in 2022. If in the S9+ or S9- variant of the test, at least one of the Salmonella strains showed a significant increase in revertants compared to the control testing, the sample is marked as positive for the presence of mutagenic substances in the sample.

In the spring campaign, the presence of direct or indirect mutagenic substances was detected in a sample taken in the Lučina – Slezská Ostrava, Bečva – Choryně, and Labe – Valy profiles. The sample from the Labe was positive for the presence of mutagenic substances even in the second campaign. In this campaign, the presence of mutagenic substances was further detected in samples from the Odra – Bohumín, Bečva – Choryně, and Bečva – Troubky profiles. In the third campaign, samples from Olše, Odra, Bečva, and Orlice were positive. In 2022, direct mutagens were repeatedly detected in samples from the Labe – Valy, Odra – Bohumín, Bečva – Choryně, and Bečva – Troubky profiles.

Test to determine estrogen potential — Yeast estrogen test (YES test)

In the samples taken in 2021 and 2022, the YES test did not significantly record the induction ratio (IR) of β-galactosidase ≥ IR10 (where IR10 = 10 % (IRmax of the standard – IR of the negative control)) (*Tab. 7a* and *7b*). The YES test did not show results indicating the presence of substances that would cause the expression of the reporter gene and the subsequent production of β-galactosidase to such an extent that the sample could be significantly marked as positive for the presence of estrogens or substances with estrogenic effects on the hER receptor. For six samples in 2021, the IR value was above 6 % of the maximum induction of β-galactosidase (*Tab. 7a*, highlighted). In *Tab. 7b*, two values in the third campaign (sample from the profiles Bečva – Troubky and Labe – Valy) are clearly marked, for which the IRmax value was above 9 %. If the value of these samples were ≥ 10 %, they would already be samples with a proven agonistic estrogenic effect. To verify the obtained results, the samples for which the maximum β-galactosidase induction value exceeded 6 % will be reanalysed by the YES test.

Tab. 7a. Results of estrogenic activity of samples in yeast estrogen tests (YES test) (2021)

Profile	% induction IRmax		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – river mouth	*	< 4 % max. induction	**8.2 % max. induction**
Opava – Krnov	< 4 % max. induction	**10.5 % induction**	< 4 % max. induction
Lučina – Slezská Ostrava	< 4 % max. induction	< 4 % max. induction	< 4 % max. induction
Ostravice – Ostrava	< 4 % max. induction	*	< 4 % max. induction
Olše – river mouth	< 4 % max. induction	**10.9 % induction**	< 4 % max. induction
Odra – Bohumín	*	*	< 4 % max. induction
Bečva – Choryně	7.1 % max. induction	**10.7 % induction**	**8.4 % max. induction**
Vsetínská Bečva – river mouth	< 4 % max. induction	< 4 % max. induction	< 4 % max. induction
Bečva – Troubky	< 4 % max. induction	< 4 % max. induction	< 4 % max. induction
Orlice – Nepasice	< 4 % max. induction	x	< 4 % max. induction
Labe – Valy	< 4 % max. induction	x	7 % max. induction

* cytotoxicity of samples recorded
x sample not taken

Tab. 7b. Results of estrogenic activity of samples in yeast estrogen tests (YES test) (2022)

Profile	% induction IRmax		
	1st campaign	2nd campaign	3rd campaign
Hvozdnice – river mouth	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Opava – Krnov	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Lučina – Slezská Ostrava	6.6 % max. induction	*	< 6 % max. induction
Ostravice – Ostrava	7.2 % max. induction	*	< 6 % max. induction
Olše – river mouth	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Odra – Bohumín	< 6 % max. induction	< 6 % max. induction	6.2 % max. induction
Bečva – Choryně	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Vsetínská Bečva – river mouth	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Bečva – Troubky	< 6 % max. induction	8.2 % max. induction	**9.0 % max. induction**
Orlice – Nepasice	< 6 % max. induction	< 6 % max. induction	< 6 % max. induction
Labe – Valy	< 6 % max. induction	< 6 % max. induction	**9.3 % max. induction**

*cytotoxicity of samples recorded

DISCUSSION AND CONCLUSION

Our measurements showed that even on the reference profiles, where the routine monitoring of selected parameters (carried out by Povodí state enterprises) showed long-term good water quality, chronic effects of pollution or their genotoxicity were determined in samples from some campaigns. This fact shows that routine monitoring apparently did not detect the substances or their mixtures that could cause the given effects, and the financial resources spent on its implementation therefore did not bring the required results for the assessment of the ecological water status, which is significantly influenced by the effect of pollution determined using EBM. In a situation where the list of priority and emergent pollutants to be monitored in waters is still growing, EBM has the potential to focus chemical monitoring on a purposeful basis, and thus to streamline its costs.

According to the Water Framework Directive, assessment of the chemical status and ecological status/potential of surface waters is carried out by monitoring priority substances and specific pollutants defined at the national level (in the Czech Republic according to Government Regulation 401/2015 Coll. and ČSN 75 7221 standard). However, these hazardous substances make up only a fraction of the total water toxicity. Chemical analysis is not able to cover all pollutants present in waters; therefore, the environmental impact of unregulated substances, as well as the effects of mixtures, is not considered.

Framework Directive 2000/60/EC requires Member States to set environmental objectives for each water body. If this goal is not met, the causes must be identified so that effective measures can be taken. For this purpose, it is necessary to have a suitable diagnostic system; however, such a tool is not often available. Most biological methods used according to the Framework Directive may not respond adequately to the presence of toxic substances and their mixtures in waters, or to other types of stressors. EBMs can provide overall information on the ecotoxicological effects of surface water pollution, and thus help in the evaluation of possible causes of unsatisfactory water status.

Based on the experience we have gained and the test results, it can be concluded that our project has demonstrated the applicability of the proposed EBM in routine practice and fully supports their introduction not only here, but also at the European level.

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Interview with prof. Ing. Pavel Pech, CSc., professor at the Czech University of Life Sciences Prague

Will world conflicts in the future be over water rather than oil and land? Why is he more afraid of genes than climate change? And is it better to build dams and large water reservoirs, or establish ponds, wetlands, and pools? What is his opinion on artificial intelligence? These are just some of the topics that I discussed with prof. Ing. Pavel Pech, CSc., long-time head of the Department of Water Resources and Environmental Modeling at the Czech University of Life Sciences (CULS). "I'm from Hnojárna,"* he says about himself with a smile, and it does not sound pejorative at all – after all, he is the founder of the Faculty of Environmental Sciences at CULS in Prague.

Professor, during our recent meeting you told me that you have been teaching at CULS for 33 years. However, you yourself graduated from CTU. What do you think about the current relationship between these two institutions? Do they compete, or rather cooperate?

Considering that I graduated from the Faculty of Civil Engineering in the field of Water Management and Water Structures, I am a technical person. In 2004, at the Department of Water Resources and Environmental Modeling, we accredited the Environmental Modelling study programme, which could be considered as a potential competitor of the Faculty of Civil Engineering at CTU in Prague. But in fact, the representatives of the Faculty of Civil Engineering actually teach in this programme. After the establishment of the Faculty of Environmental Sciences and the subsequent accreditation of the doctoral, habilitation, and professorship programme in Environmental Modelling, representatives of water management from CTU became members of the Field of Study Board. For some time then, I was a member of the Field of Study Board of Environmental Engineering at the Faculty of Civil Engineering. The current head of the department, Prof. Martin Hanel, continues to be a member of this Field of Study Board, who further deepens cooperation with the Faculty of Civil Engineering, for example in organizing joint conferences. Teachers from the Faculty of Civil Engineering regularly participate in the defence of bachelor's, master's and doctoral theses, as well as chairpersons and members of state commissions. Therefore, in my opinion, cooperation with the Faculty of Civil Engineering in the field of water management is positive and correct.

You spoke about the Faculty of Environmental Sciences, which you helped to establish. When was that and what preceded its establishment?

In 2003, when I was acting as Vice-Dean for Education at the Faculty of Forestry, as a member of the landscape-ecological part, I participated in the renaming of the faculty to the Faculty of Forestry and Environment. Later, the university began to think about a greater involvement of the university in the field of the environment by creating an institute or a new faculty. The result was that in April 2007, CULS Rector, Prof. Jan Hron, entrusted me as the guarantor of the establishment of the new Faculty of Environmental Sciences, and then Dean of the Faculty of Forestry and Environment, Prof. Vilém Podrázský, with the establishment of the Faculty of Forestry and Wood Sciences. After about two months of intensive work, with the help of the Department of Water Resources and Environmental Modeling, it was possible to prepare all the documents for the establishment of the new faculty. I would like to highlight at least one name, Dr. Jiří Pavlásek, who helped a lot and later, after the establishment of the Faculty, mainly participated in the consolidation of the education part, including the subsequent preparation of the accreditation of the bachelor's field of Water Management. At the field meeting of the Accreditation Commission in Pavlov on 18–20th June 2007, the division of the Faculty of Forestry and the Environment and the establishment of the Faculty of Forestry and Wood Sciences and the Faculty of Environmental Sciences from 1st July 2007 were approved. The staff of the landscape and ecology departments moved from the original faculty to the newly created faculty; The Accreditation Commission of the Ministry of Education, Youth and Sports also agreed to the transfer of three bachelor's, four master's, four doctoral fields of study, as well as one habilitation and three habilitation and professor's fields of study. Subsequently, the Rector appointed me to the position of "Person entrusted with the management of the Faculty of Environment Sciences" until the regular Dean elections, which took place in December 2007. Between 1st July and 6th December 2007, I was arranging the functional mechanisms for the Faculty with the authorized management. It was interesting that less than two months passed from the decision to the approval of the Faculty establishment.

At the master's and doctoral programme, you offer over ten professional subjects, including studies in English. Do you have a lot of international students at your university?

Currently, I guarantee eleven subjects – five in the bachelor's, four in the master's, and two in the doctoral programme, of which three subjects are taught in English. During the academic year, approximately 20 to 25 students take part in English subjects. Around 1,500 foreign students study at CULS every year.

Could you please compare the construction of dams around the world with our country? Where do you see the differences in these conditions, for example, when compared to Austria or Poland?

Compared to other European countries, the construction of dams in our country was at a similar level in the 20th century. I am not an expert in the design or construction of dams; however, I can see that the current situation in this area is not good. Let me give you one example. After the floods in Moravia and Poland in 1997, both countries began to address the situation by considering the construction of a dam. Nové Heřmínovy in the Czech Republic, and Ratiboř in Poland. Both dams should be used for flood protection – on the Polish side it was supposed to be a dry polder for a period of five years, which should be converted into a classic water dam holding 180 million m^3 of water, and on the Czech side the new dam was supposed to capture around 14 million m^3 of water, of which 3.5 million m^3 would be used for drinking purposes. On the Czech side, a zoning decision for the construction of the dam was approved in June 2023. The construction should begin in 2027 and the dam should be completed in 2032. Although considerations about the construction of dams started at the same time, the Polish side already opened the waterworks in 2020, which, by the way, was designed to hold ten times more water.

From the above case, a different approach to the planning, approval, and construction of dams is clear. It should be noted that for a quick and successful solution to water management issues related to climate change, water management issues should be included in the responsibility of one ministry; or, given the importance of the issue, it deserves its own ministry. Currently, in our country, water management issues are integrated into two ministries, which by their very nature have different priorities in this area.

Do you think that Czech natural conditions allow the construction of such dams? And if a new dam were to be built, would it be possible to get enough water to fill it?

Natural conditions certainly allow the construction of other necessary dams, which is evidenced by the plans mainly coming from the Ministry of Agriculture. In my opinion, climate change will force some dams to be built. My previous answer shows my rather pessimistic view of their implementation in our country. A comparison of the length of building permits in different countries was recently published in the press, and the Czech Republic is in about 160th place in the world, even behind countries such as Congo or Rwanda. In order to ensure (not only) enough drinking water, but also water for agriculture and to maintain sufficient flows in the rivers in the near future, it will be necessary to significantly speed up and make the decision-making and implementation more efficient. The approval and construction of dams on some Czech rivers will have to happen, hopefully as soon as possible, because a dam will not be built in a year or five years and climate change will not wait. And to your question about enough water to fill them. According to experts on hydrology, the total volume of precipitation does not change significantly over the years – even in times of climate change – but their intensity and time distribution throughout the year do. One example regarding getting enough water to fill a new dam; if you take only the flow of 0.3 m^3s^{-1} from the total flow on the river, it would take about five months to fill Nové Heřmínovy dam.

Do you think it is better to focus on the construction of large water reservoirs, or rather build or restore ponds, pools, and wetlands?

Personally, I would not prioritize any of the listed measures. However, it will be necessary to focus on building these structures in parallel – each of them has its own importance. Various studies show that semi-natural measures only help with the water balance by about eight to ten per cent, so it will be necessary to proceed with the construction of both smaller and larger dams, which are often wrongly perceived negatively by the public. Regarding, for example, ponds and wetlands, they do not help the water balance much with their usable volumes. They may have problems in the near future due to the increasing amount of water vapour. I would not say that it is better to focus on building bigger dams, but it will be necessary for maintaining "water comfort". There are already places in the Czech Republic that have great difficulties in securing sufficient water during dry periods. So far, it has been "forgotten" that the use of groundwater is an inseparable part of the strategy to ensure sufficient water in times of climate change. The advantage of groundwater is that there are no evapotranspiration losses. From the balance of drinking water used, it follows that 50 per cent of the Czech Republic is actually groundwater, which gradually leads to a reduction in its reserves. Therefore, artificial infiltration should also be implemented, which can be a suitable source of water in the dry season. Artificial infiltration began to be used to enrich groundwater supplies at the beginning of the 20th century. This is also where the history of the Káraný waterworks begins, built according to a project of one of the classics in the field of groundwater, Adolf Thiem, in 1919. An artificial infiltration system has been operating in Káraný since 1968, but its further use is very sporadic in our country. A number of scientists have been dealing with this issue within grants, including practical applications. In projects related to groundwater, I rather concentrated on the efficient use of so-called "actual wells", because in many cases the constructed networks of underground wells are used by water management companies, and as long as a sufficient amount of water is pumped from the wells for treatment, the companies do not care about their condition. The clogging (aging) of wells and a noticeable drop in abundance then leads to their complete depreciation, while timely intervention can maintain the well's productivity at a sufficient level for many decades.

It seems to me that much of the information that the media is flooding us with on an almost daily basis regarding climate change is already approaching the spread of an alarmist message. Do you believe that the current situation is already irreversible?

Much information from the media about climate change is currently rather one-sided and presented in a pessimistic or even depressing manner. If people get information presented in this way from the media, it can cause a certain kind of apathy, depression and resulting psychological problems in many of them, which we also know from the recent covid pandemic. This massive and often one-sided information "massage" can be taken as a "mediocracy", i.e., the government of the media, with a huge influence on human thinking and the actions of human society. It would probably be more reasonable to try to inform as truthfully as possible in the press, taking into account the different opinions on the matter, mention the uncertainties in connection with climate change, and point out that there are real ways out of this critical situation and ways of adapting to the given situation. Nowadays, it is clear that climate change is happening; however, it is necessary to take into account other opinions when explaining it, for example, that the opposite process to what is happening now, i.e., cooling, can theoretically occur. These theories are also presented by scientists from reliable sources, for example the recent reports from NASA. If we take into account that the theory of global warming works, there are a number of options in the field of water management to effectively respond to this change – be it semi-natural measures, building reservoirs, connecting water management (water supply) systems and so on; however, it is necessary to implement these measures in the foreseeable future, and not as was presented in the case of Nové Heřmínovy dam.

During our meeting, I was very interested in your mention that you fear gene manipulation more than climate change. Could you please explain this to our readers?

Let me clarify. If climate change continues, I am also concerned about the consequences, especially in terms of sufficient water availability in various parts of the world. From places with catastrophic situation with water resources, masses of people will head towards places where there is still enough water. It will not be a matter of millions of people, but tens to hundreds of millions. These shifts will cause the steep fall of advanced civilizations.

Going back to the concern about genes. Firstly, these are genetically modified crops, in which the hereditary DNA material is changed using gene technologies, and although most scientists assure the safety of the mentioned procedures, many of them have more cautious opinions in assessing their harmlessness; according to them, possible negative effects on humans may manifest themselves only after decades or even in the following generations. Secondly, and this is even more serious, is the direct intervention in the organism's genome using modern DNA technologies involving the introduction of foreign genes into the organism. For example, in 2018, in China, they used revolutionary new genetic methods of altering a human embryo. After this intervention, twins were born who had genetically altered DNA. At the current level of knowledge, it is not possible to reliably demonstrate how gene manipulations can interfere with life and how it will continue to affect it.

We talked about the technicized era, as well as the very rapid development of artificial intelligence. What is your opinion about it and how do your students perceive it?

The rapid development and application of artificial intelligence brings great expectations, but also concerns. It is clear that artificial intelligence (AI) is already beneficial in a number of areas and in different fields. As an older person, I remember well the sci-fi movie "The Terminator", which could gradually become a reality. In this film, a pessimistic scenario is shown with the use of artificial intelligence, which at a certain point discovers that it no longer needs humans for its existence – it can learn, make decisions, change, adapt, and so on. To ensure fulfilment of Isaac Asimov's three well-known laws of robotics (AI can be substituted for the word "robot") –"1) *A robot must not injure a person or, through inaction, allow a person to be harmed; 2) A robot must obey orders given to it by humans, except where such orders would be contrary to the first law; 3) A robot must protect its own existence if such protection does not conflict with the first or second law"* – becomes unrealizable, due to its nature and origin. From the occasional debates with students, it appears that they do not have a problem with the use of AI, and most of them have no concerns about the future. I learned from a faculty colleague that one of the students used AI to write a bachelor's thesis, but at the current level of AI it was easily identified and the student failed the thesis. However, AI is in its early stages of development and it is moving forward very quickly. It is necessary to prepare well for its effects in the future.

Do you think there is a risk of water wars in addition to other world conflicts in the future?

I remember that years ago, the former Chief of the General Staff of the Army of the Czech Republic said in an interview that future military conflicts are not expected to be about oil, but will be related to battles over water and its resources. This issue is presented very well in the three-part Norwegian documentary "The Future of Water", and I recommend watching it for those interested in water management issues. The author of the document is Prof. Terje Tvedt from the Universities of Bergen and Oslo. He travelled all continents and created an excellent documentary about water and its problems and outlined possible solutions. The individual parts have apt names: "Rulers of Water", "New Uncertainty", "Age of Water". The war for water resources in the past is shown using the example of the Republic of South Africa. In 1986, it signed a water supply agreement with Lesotho and participated in the construction of a large dam. In 1998, there was a threat of a coup in Lesotho and a refusal to supply water to the Republic of South Africa. Its president at the time, Nelson Mandela, ordered a direct air strike, which solved Lesotho's water supply problem. Other potential water resource fights threaten Africa, such as the Nile. Sudan and Ethiopia have built huge dams with China's help, thereby disrupting the stability of the Nile water supply system in, for example, Egypt. With ongoing climate change, the situation is intensifying and there is a threat of explosive conflict between countries dependent on the Nile water. Another example are the war conflicts in Asia. In the Himalayas, at altitudes of around 6,000 m above sea level, a secret war has been going on for more than twenty years over the sources of water from the Himalayan glaciers, called the "Battle in the Skies". This conflict between India and Pakistan is all the more dangerous because they are nuclear powers, and its escalation threatens severe consequences.

And this is just a small sample of the ongoing war over water resources. It is necessary to prepare for the fact that if climate change continues at the pace that we can observe now, then, in my opinion, there is a high risk of significantly larger military clashes over water resources.

Regarding the lack of water, how would you deal with very dry areas in South Moravia or Rakovník district, for example? In comparison with the world, you told me that the Chinese, for example, are able to conduct water through open channels and underground to very distant places, within hundreds to thousands of kilometres.

First, a note on China and its water management issues. The south of China has plenty of fresh water, but its northern part has only twenty per cent of the fresh water available in the whole country, even though it contains two-thirds of China's arable land. China has been dealing with this issue since the 1950s. The total length of tunnels and open channels currently being built or planned to transfer water from the south to the north will reach 20,000 kilometres when completed. For example, in 2014, China opened a channel to transfer 54 billion m^3 of water. The commissioning of the canal brought the unexpected effect of a significant increase in the groundwater level in some places. At the same time, China is building the world's longest water tunnel to transfer water from the Three Gorges to Beijing. The entire transport network measures 1,400 kilometres, which is a gigantic, even megalomaniacal construction, which of course we cannot compete with.

Now for the first part of your question. Our society must deal with the lack of water in South Moravia, Rakovník district in Polabí, and in the foothills of the Ore Mountains in the shortest possible time. The individual Povodí State Enterprises have already prepared or are preparing solutions with the construction of the necessary dams, and at the same time the connection of water supply systems is prepared or planned. We have a very good example from the past that it is possible to build such structures. For example, in 1972, a 51-kilometre-long tunnel was completed – the longest water transfer tunnel in Central Europe – leading from the Želivka reservoir to Prague. The water from Želivka supplies drinking water not only to Prague, but also Beroun, the surroundings of Kladno, and partly the Vysočina region. I will return to the situation in our country. "Mediocracy" should do away with climate scaremongering and concentrate on the vital water issues and their solution in the period of climate change, so that instead of lookout towers, cycle lanes, electromobility and many other "necessary" things, it puts pressure on public opinion and, above all, on political representation. There must be accelerated strategic decision-making and the implementation of necessary water management structures and measures because we all know that without water there is no life. And I will add that larger water management structures will not be built in this country in five, ten, or even twenty years, although if there is will, it can be done in significantly shorter time.

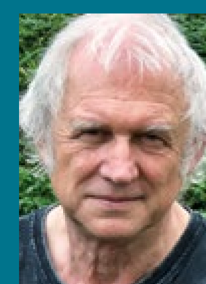
Finally, I want to talk about your students again, Professor. You have been teaching for 33 years, so you certainly have the opportunity to compare the level and knowledge of those today compared to three decades ago. You mentioned that the number of students in both water management and environmental modelling continues to decrease. How do you explain that?

If I compare my studies and today's teaching, there is quite a big difference, not in the content of, for example, hydraulics that I teach, but in what today's students are capable of, but also willing to learn. Allow me a small note that also clarifies my experience of more than 30 years of teaching, and nowadays a decline in the quality of teaching can also be observed, which is logical. About 20 years ago, as Vice-Dean for Education, I attended a seminar held in connection with the preparation of the state "matriculation" exams. At this seminar, neuropathologist Dr. František Koukolík gave a lecture, and his excellent presentation showed that over the course of generations, 12 to 14 per cent of the population year had the prerequisites to successfully complete university studies. At that time, he said in his lecture that 60 to 70 per cent of the population year goes to university to study and this amount of students has an effect on the quality of students, but is naturally also reflected in the quality of the teaching process (I apologize for possible inaccuracies in the quotation from this lecture). Now a specific example from my experience. When asked about their knowledge of Archimedes' law, many students – and it is not a small number – are unable to interpret it correctly, even after completing the hydraulics subject. During one of my visits to my wife's mother (she is more than 80 years old, comes from a farm, and after finishing primary school, she worked in the forest all her working life) I tried to jokingly ask if she knew Archimedes' law. And the result – not only did she tell me the whole thing correctly, but she even explained it. And finally, to the last part of the question. After the accreditation of the Environmental Modelling programme, between eight and fourteen students from various fields of study at Faculty, but also from other faculties and even from Charles University, studied it every year. The level of these graduates was excellent. The evidence is their application in practice, at the Faculty, in the institutes of the Academy of Sciences (Institute of Hydrodynamics, Institute of Thermomechanics), in the company DHI, a. s., but also in TGM WRI, and graduates have also applied abroad – in Germany, Great Britain, etc. Subsequently, there was a gradual decrease in interest in this field, and the interest of students in the bachelor's field of Water Management and the master's field of Water in the Landscape is also decreasing. My explanation for this is that once students find out that they should study technical field of study and with it mathematics, physics, hydraulics, hydrology and other technical subjects, they prefer to take the easier route to get university education. And so, at the end of the interview, I will add one more statement – in the near future, there will be a shortage of university-educated water managers in the Czech Republic.

Professor, thank you very much for the pleasant meeting and for the time you devoted to our interview.

Mgr. Zuzana Řehořová

Prof. Ing. Pavel Pech, CSc.



Prof. Ing. Pavel Pech, CSc., born on 31st January 1955 in Beroun, graduated in Water Management and Water Structures at the Faculty of Civil Engineering of the Czech Technical University in Prague. After graduating in 1979, he joined Vodní zdroje, state enterprise, where he worked on issues related to well hydraulics. In his doctoral thesis at the Department of Health Engineering of the Czech Technical University, he also dealt with the issue of hydrodynamic tests on wells, the creation and evaluation of additional resistances in the well and its immediate surroundings. He defended his thesis in 1985. He then moved to the Institute of Hydrodynamics – then the Czechoslovak Academy of Sciences – and dealt with the issue of oscillatory flow in the cardiovascular system in the Department of Biomechanics, and later with numerical modelling of flow in reservoirs in the Department of Hydrology. In 1990, he started working at the Czech Agricultural University, later the Czech University of Life Sciences in Prague (CULS). In 1995, he obtained his habilitation in the field of Hydroinformatics, and in 2005 he was appointed professor in the field of Agricultural and Forestry Hydrology. At CULS, he started his teaching carrier with practical lessons in Hydraulics and Small Water Courses. He currently teaches the subjects of Hydraulics, Surface and Groundwater Hydraulics, Groundwater Hydraulics, and also Hydraulics and Groundwater Hydraulics in English. He participated in and later led a number of practically focused grants issued by the Ministry of Agriculture, the Ministry of the Interior, and the Technology Agency of the Czech Republic (TA CR). Recently, he has led TA CR grants focused on the sustainable use of groundwater reserves in the Czech Republic and the introduction of new well cleaning technologies; for example, a well cleaning device using ultrasound was developed within the TA CR project in cooperation with the German company SONIC Technologies GmbH, which is now successfully used by the company VODNÍ ZDROJE, a. s.

*Translator's note:
"Hnojárna" – a pejorative term (from Czech "hnůj" – manure) used for CULS, as it was previously called "University of Agriculture").

Looking back at the National Dialogue on Water 2023

After a four-year break caused by the covid pandemic, the National Dialogue on Water took place on 25–26th October 2023, this time in the Skalský Dvůr hotel in Vysočina. The event was organized by the T. G. Masaryk Water Research Institute, p. r. i. (hereinafter TGM WRI) in cooperation with the Czech Scientific and Technological Water Management Company (Česká vědeckotechnická vodohospodářská společnost, z. s.) The main theme of the event was a comprehensive approach to the protection of drinking water sources. This topic was addressed by a large number of experts from the field of water management (118 participants), whether it was representatives of the Ministry of the Environment (MoE), Ministry of Agriculture (MoA), Ministry of Health, state-owned River Basin State Enterprises, the Czech Hydrometeorological Institute (CHMI), water authorities, operators of water supply and sewerage systems (VaK), mayors, private companies, hydrogeologists, and others.

This time the event was more focused on the discussion between the panellists, the moderator, and the participants. The event was divided into four blocks. The first block dealt with the issue of protecting water resources in the catchment area. The moderator was the director of TGM WRI, Ing. Tomáš Fojtík, who warmly welcomed everyone and created a relaxed and friendly atmosphere. Each block started with a short ten-minute presentation. The first block was introduced by Mgr. Lucie Jašíková, Ph.D., from TGM WRI. It mainly focused on the issue of risk analysis of the catchment areas, which represents a new challenge in meeting the requirements of EU Directive 2020/2184 on the quality of drinking water. Since this analysis will be processed by River Basin State Enterprises, the panel included two of their representatives: Ing. Lenka Bartošová from the Ohře Basin State Enterprise, and Mgr. Lenka Procházková from the Morava Basin State Enterprise. Other panellists included Ing. Radka Hušková, representing the Water Supply and Sewerage Association of the Czech Republic (SOVAK ČR), and Mgr. Ladislav Faigl from the MoA. The following conclusions were made:

1. The reference year for identifying raw water abstractions will be 2023 or 2024.
2. It will be necessary to add information about the groundwater body from which raw water is abstracted to the Raw Water Database (administered by CHMI).
3. It is necessary to appeal to VaK operators to properly comply with the legislative requirements of Decree 428/2001 Coll. in the valid wording, and added information on the sampling and quality of raw water to the Raw Water database (administered by the CHMI). Operators who are members of SOVAK ČR will be notified via SOVAK ČR, other VaK operators will be notified via MoA.
4. It is desirable that the catchment areas should consist of one layer processed by one entity based on one methodology, for the entire Czech Republic.
5. On behalf of SOVAK ČR, it was confirmed that VaK operators will monitor relevant indicators of raw water based on recommendations resulting from the risk analysis of the catchment areas.
6. In the subsequent evening discussion, it was proposed that TGM WRI and CHMI should assist the River Basin State Enterprises with risk analysis of the catchment areas for groundwater abstraction.

The second block was moderated and introduced by RNDr. Josef Vojtěch Datel, Ph.D., from TGM WRI. He presented the topic of water resource protection zones (OPVZ), their current legislative framework and records. Among the speakers were experts from state administration (Dr. Ing. Marcela Burešová, MPA, from the Regional Office of the Central Bohemian Region, and Mgr. Martin Pták from the Department of Water Protection of the MoE), representatives of the River Basin State Enterprises (Mgr. Petr Ferbar from Labe Basin State Enterprise, RNDr. Jindřich Duras, Ph.D., and Prof. Ing. Tomáš Kvítek, CSc., both from Vltava Basin State Enterprise), as well as representatives of hydrogeologists from private companies (Ing. Jakub Průša from Severočeské vodovody a kanalizace, a. s., and RNDr. Svatopluk Šeda from FINGEO, s. r. o.).

The main conclusions were:

1. It is necessary to continue to maintain the OPVZ institution, but also to significantly modify (modernize) it.
2. As the current options for even partial revisions of the OPVZ are limited, it is necessary to achieve "flexible updateability" of measures (based on risk analysis results).
3. It is necessary to change control mechanisms and tools of a motivational and restrictive nature.
4. Comprehensive protection of water quality and quantity must always be functionally linked.
5. Appropriate methodological tools must be provided to address the previous points. However, the issues of protection of groundwater and surface water resources must be dealt with separately.
6. An effective comprehensive solution means reducing and slowing down surface and subsurface runoff, as well as increased emphasis on water infiltration in an anthropogenically unburdened environment and protection of the area where infiltration occurs. The measures combine semi-natural processes and technical elements linked into a functional unit (both in the countryside and in urbanized sites).
7. The combined approach to water reservoirs should also include the possibility of water supply use of reservoirs that do not fulfil a water supply function.
8. It is necessary to establish an interdisciplinary working group to develop the above-mentioned theses.

The third block started with a presentation by doc. RNDr. Zbyněk Hrkal, CSc., from TGM WRI. His topic was drinking water quality with a focus on "emerging substances" such as pharmaceuticals, pesticides, per- and polyfluoroalkyl substances (PFAS), and others. The discussion was led by Mgr. Vít Kodeš, Ph.D., from CHMI. The panellists included MUDr. František Kožíšek, CSc., from the National Institute of Public Health, Mgr. Milan Koželuh from the Vltava Basin State Enterprise, Mgr. Marek Skalický from Káraný Waterworks, and Ing. Radka Hušková from SOVAK ČR.

The conclusions were as follows:

1. Legislation for drinking water currently sufficiently treats the occurrence of substances that are not specifically listed in the legislation.

2. Analytics is done according to substances of which we are aware of – the selection of monitored representatives of individual groups of substances is decided according to the amount and frequency of use (medicine), known pollutants are monitored depending on the industry, specific pollutants according to risk of occurrence.

3. PFAS – monitoring of their occurrence in drinking water and monitoring of their sources is ongoing; so far it does not appear to be a widespread problem. It is necessary to address measures at the source of their occurrence, including restrictions on their use.

4. In the case of pharmaceuticals, the question is how to grasp the "polluter pays principle", whether it is possible and meaningful to address measures at the source. We know very little about the cycle of pharmaceuticals in the aquatic environment. We are concerned with their concentration, but not with balance. It is desirable to direct research to deepening knowledge.

5. With regard to the economic impacts of the desired removal of drugs and other micropollutants, a new approach to pricing is necessary. A call was formulated for the MoA and the MoE to set up a working group to deal with this issue.

The last summarizing block was moderated by Ing. Karel Drbal, Ph.D., from TGM WRI. Both the panellists and the participants discussed the main conclusions from the first to third blocks (Ing. Tomáš Fojtík from TGM WRI, Mgr. Jiří Paul, MBA, from VaK Beroun, a. s., RNDr. Pavel Punčochář, CSc., from MoA, Mgr. Mark Rieder from CHMI, Dr. Ing. A. Tůma from Morava Basin State Enterprise, and M.Sc. Lukáš Záruba from MoA). All the National Dialogue participants agreed that the protection of water and above all water resources is key and that it should be a priority for all citizens of the Czech Republic. However, this protection must be comprehensive and the legislative, economic, and educational topics must be optimized. Simultaneously, it is very important that the general public is much more aware of this issue. However, the basis for this protection should be long-term concepts and visions upon which experts from all fields of water management could rely. The National Dialogue on Water 2023 tried to outline some of these visions.

It is possible to download the main conclusions from the National Dialogue here [1].

References

[1] https://www.vuv.cz/wp-content/uploads/2023/10/Seminar_NDoV_IV_20231027.pdf

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Kozmice bird meadows and their importance for nature and landscape

INTRODUCTION

Alluvial wetlands and alluvial meadows (often referred to as "wet" in the literature) are one of the types of habitats that, with the gradual development of the cultural landscape, suffered the greatest transformation and often complete disappearance; in the Czech Republic, the most significant transformation by the transfer to field crops together with land improvement peaked roughly in the 1970s. Discussions about the importance of wetlands have, however, been revived in different periods; the factors that trigger these discussions are mainly floods and drought, which is clearly indicated by the drought that started in 2015. In their name, alluvial wetlands and meadows indicate that they are situated in a river landscape and are in periodic or constant contact with the surface water of larger rivers and groundwater, including the hyporeal. It is therefore obvious that these landscape elements are at least locally important for the cycle of water and chemical substances in the river landscape. These hydrological effects are already fairly well described in the literature today; in this respect we can mention the essential works of Benstead, Drake et al [1], Štěrba et al [2], Cílek, Just et al [3], and Čížková, Vlasáková et al [4]. The importance of wetlands with regard to their historical occurrence in the Polabí landscape is also discussed by Richter [5]. The hydrological importance of alluvial meadows is indisputable; it is therefore desirable to emphasize their importance for the biodiversity of plants and animals. In addition, these habitats represent a natural and interconnected transition between terrestrial and aquatic habitats and systems in the landscape.

Description of the site and its history

Kozmice bird meadows are the largest private reserve of the company Semix Pluso, s.r.o., with an area exceeding 70 ha. They are located in the floodplain of the Opava river in the area between the villages of Dolní Benešov, Kozmice, and Ješovice. It is currently a continuous habitat of foxtail grass and sedge meadows, which was created on improved fields. An interesting fact is that in the 19th century there were ponds and mill races in this area, and the remains of the pond embankment with oak and other floodplain trees is still preserved. Of the mills, only Kolečkův mill, built in 1845, was preserved, but there were also older buildings, such as Na Osikovci mill, first mentioned in 1446, or the even older Jilešovický mill, of which there are records from as early as 1377 (Solnický, [6]). The water races remind us of the site's mill and pond history, such as Mlýnská strouha with a derivation at the weir in Smolkov, flowing through the area of the former ponds of the Dolní Benešov and Kozmice systems, or Opusta and Přehyně.

Stages

In the first stage, a reserve covering 13 ha was created as part of the MoE adaptation project *Kozmice bird meadows – restored nature*. The main purpose of this project was to achieve the following goals (adapted from Semix Pluso, s. r. o.):

- restoration of the basic functions of the river landscape (alluvium of the Opava river valley floodplain together with the Juliánka and Přehyně streams and optimization of the water regime in the landscape),
- supporting the retention capacity of the area,
- creation of new pools (11 structures with a total area of 3.27 ha),
- replacement of the channelled course of the Přehyně stream with a new meandering bed of variable width with two side pools and a flow length of 735 m,
- construction of three ramparts serving as hibernacula for amphibians,
- restoration of alluvial meadows and careful management (appropriate timing of mowing with regard to bird nesting and the development cycle of butterflies),
- planting of trees and shrubs (supplementation of existing solitary trees and the creation of a strip of shrubs along the cycle path with the aim of fencing the reserve and ensuring the necessary peace and quiet for animals),
- promotion of wildlife by building an observatory and education panels for the public,
- support for endangered and protected species (birds, amphibians, invertebrates, and fish).

Fig. 1. The site in 2000 with a predominance of agricultural land and fields (Source: WMS ČÚZK)

Fig. 2. The site nowadays with wetlands and water bodies (Source: WMS ČÚZK)

Part of the first stage was also the construction of a bird observatory for visitors, which was later renamed Petr Čolas Observatory – in honour of the late director of the Ostrava Zoo.

During the second stage in 2017 and 2018, the reserve was expanded to include additional aquatic and terrestrial habitats and features. The third stage took place in 2020 and 2021, triggered also by the impact of floods on the area; it involved allowing natural flooding and, simultaneously, creating refuges for the animal inhabitants of Kozmice bird meadows, including Exmoor ponies.

Importance of the site for nature and landscape

If we focus on the importance of the Kozmice bird meadows for retaining water in the landscape, even the extremely dry period of 2015–2019 did not cause the complete drying out of the site. In addition, since the third stage, the number of water bodies and wetlands has increased, so this effect has become even stronger. Soil moisture is also positively affected by the existence of a developed and varied meadow community, which is in good condition thanks to grazing by Exmoor ponies. The specific effects of grazing large ungulates on these communities and related invertebrate and vertebrate species, including rare species of butterflies or waders, can be found in Jirků, Dostál [7] and Danell, Duncan et al [8]. The positive effects include the grazing itself (horses choose fast-growing species that would dominate without grazing) and disturbance of the soil by hooves, which increases species diversity of the herb layer during periodic waterlogging of the site. Another positive effect of the presence of wild horses is the "protective factor" for bird species; waders in particular seek their presence and are much calmer than usual. This general tendency was also manifested in the area of Kozmice bird meadows, where there is a stable population of northern lapwing

Fig. 5. The Exmoor pony is a beautiful animal…

Fig. 3. A young roe deer is discovering the world

Fig. 6. … as well as very resilient and undemanding

Fig. 4. Kingfishers thrive in Kozmice bird meadows

Fig. 7. It is used to water and is connected with water

Fig. 8. Morning sun over Kozmice bird meadows

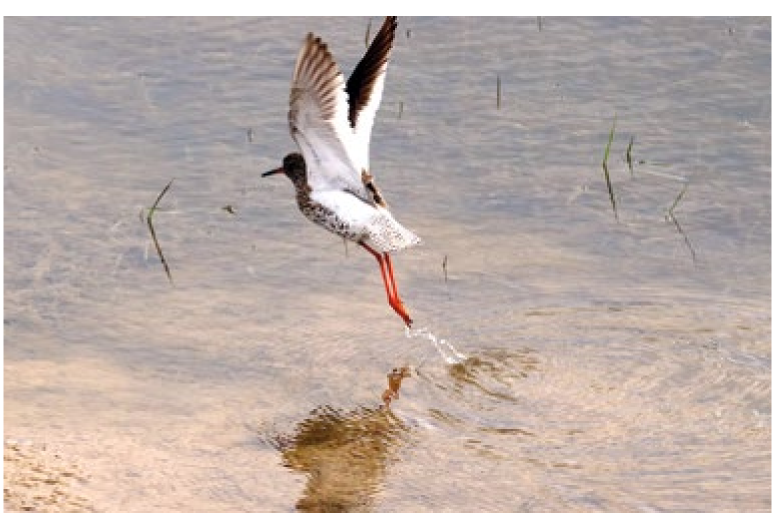

Fig. 9. Common redshankredshank

Fig. 10. Great egret in the morning sun rays

(*Vanellus vanellus*) and common redshank (*Tringa totanus*), both waders. Other species of *Tringa* are also regularly present here, such as common greenshank (*Tringa nebularia*), as well as another representative of waders, Eurasian curlew (*Numenius arquata*), which is rarely found in the Czech Republic. Among the other interesting and exceptional species of water and wetland birds, several species of heron regularly appear on the site, such as little egret (*Egretta garzetta*). A significant moment in the history of the meadows was the nesting of common goldeneye (*Bucephala clangula*). The increasing number of breeding pairs of greylag geese (*Anser anser*) is complemented by the transient appearance of greater white-fronted geese (*Anser albifrons*) during the spring and autumn migration. Ducks that are rarer or less common in the Czech Republic include garganey (*Anas querquedula*) and northern shoveller (*Spatula clypeata*). The rare songbird species that can be found in the meadows include reed bunting (*Emberiza schoeniclus*). However, the real gems and successes of the reserve undoubtedly include the regularly recurring appearance of common crane (*Grus grus*) and its first successful nesting at this site this year. The aforementioned grazing of wild ponies, which supports the diversity of nectar-bearing herbs, also positively affects the occurrence of great burnet (*Sanguisorba officinalis*), and thus also the nearly endangered dusky large blue butterfly (*Maculinea nausithous*). A big advantage of the Exmoor pony is the fact that, compared to domesticated horse breeds, it is much tougher and has a higher immunity to parasites, so it is not necessary to feed it (with exceptions such as frost and flooding). At present, the herd at the Kozmice bird meadows consists of 26 stallions, mostly of a young age. During last year and this year, the numbers of large ungulates were supplemented by a herd of ten Highland cattle. In addition to their indisputable importance for the wildlife and landscape of Hlučín and Opava, Kozmice bird meadows are also an attractive destination for day trippers. However, if visitors want to observe the rare and interesting species of animals found here, it is necessary to behave sensitively and quietly, which should generally apply to all natural sites.

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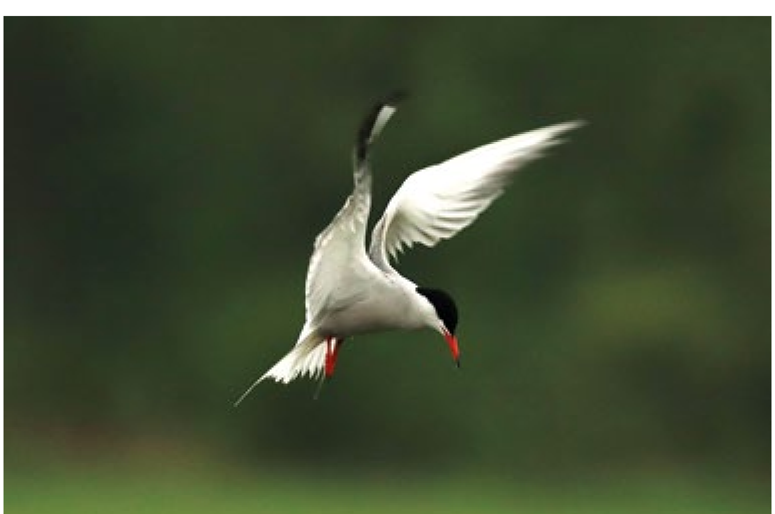

Fig. 11. Common tern

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WATER TREATMENT PLANT IN VÍTKOV-PODHRADÍ

The water treatment plant in Podhradí (part of Vítkov municipality) is located in the Moravian-Silesian region, about 18 km south of Opava. It is the oldest water treatment plant in the Odra basin and is also one of the largest water treatment plants in the Czech Republic, with a production capacity of 2,700 l/s. It was built between 1954 and 1962, at the same time as Kružberk waterworks, and is part of the water supply system of the Ostrava regional water supply system. It is connected to Kružberk by a 6.7 km tunnel, which brings raw water to the treatment plant, where it is purified for drinking purposes and then distributed mainly to the Ostrava region, but also to the surroundings of Fulnek, Bruntál, and the Přerov region.

The treatment plant building is an example of an industrial technical building by architect Cyril Kainar. It consists of a reinforced concrete frame with brick linings. In its floor plan view, the axisymmetric layout of the building evokes the shape of an airplane or a flying bird. The architect used the unique concept of two independent parts for purifying and for treatment of raw water, mirroring each other. The facade of the building is decorated with a large relief, the last work of sculptor Vincenc Makovský, from 1961–1964 from the cycle Water in our Life. For this reason, the building has been listed since 1974.

Within the necessity of reconstruction and modernization of technology, it is an example of finding a compromise between the requirements of operation and heritage protection. In the case of technology, the authenticity of the function is superior to the authenticity of the material and technical equipment. From an architectural point of view, the search for a compromise is conducted so that the building remains a document of the architecture of its time, while its value is not degraded.

Text by Ing. Miriam Dzuráková and Mgr. David Honek, Ph.D.; photo by Mgr. Radek Bachan.

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