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

# VTEI/2022/4

# 6 August – International Day for the Total Elimination of Nuclear Weapons (Hiroshima Day)
# 9 August – Nagasaki Day

On the 6th and 9th of August, the whole world will commemorate the 77th anniversary of the dropping of two nuclear bombs on the Japanese cities of Hiroshima and Nagasaki.

In the summer of 1945, the war in Europe was already over and the participating countries were counting their dead. The war in the Pacific was also coming to an end. However, Japan refused to surrender and did not accept the ultimatum presented by the Potsdam Declaration, even after six months of strategic bombing of many dozens of Japanese cities. Therefore, the government of the United States of America decided on a drastic solution. First, an atomic bomb called *Little Boy* was built, which contained 60 kilograms of uranium 235. It was dropped on the 6th of August 1945 on the city of Hiroshima, which served as a base for Japanese soldiers. Due to a side wind, however, it did not hit the originally planned bridge, but a clinic 240 metres away, where, among other things, it killed most of the doctors and nurses of Hiroshima at the time.

However, despite the huge loss of human life, Japan continued to refuse to capitulate, even after the Soviet Union declared war on it on the 8th of August. Therefore, on the 9th of August, it was decided to use the second atomic bomb called *Fat Man*, which contained 6.4 kilograms of the synthetic element plutonium 239. Even here, the bomb was not dropped on its original destination, which was the city of Kokura. After the arrival of the plane carrying the nuclear weapon, it was 70 per cent hidden by clouds, and therefore it was dropped on the secondary target, the large seaport of Nagasaki. Only then did Japan announce its agreement to surrender and sign the surrender document on the 2nd of September, definitively ending the war in the Pacific and officially World War II.

Scientists and military experts are still debating whether the use of two nuclear bombs was necessary or appropriate. Immediately after the Soviet Union declared war on Japan on the 8th of August 1945, the Western powers agreed that it was necessary to intimidate not only Japan, but also Stalin because they feared the occupation and subsequent Sovietization of all of Europe. Unfortunately, this threat is relevant again after 77 years – what seemed unreal and distant to us is dangerously close after the outbreak of the Russian-Ukrainian war. So we can only hope that all the victims – numbering hundreds of thousands who died immediately during the explosions and in the following years from radiation diseases – were the first and at the same time the last victims of nuclear weapons in the history of mankind.

Editorial VTEI

The Hiroshima Peace Memorial (Genbaku Dome) are the ruins of a building designed by Czech architect Jan Letzel. In 1996, it was designated as a UNESCO World Heritage Site.

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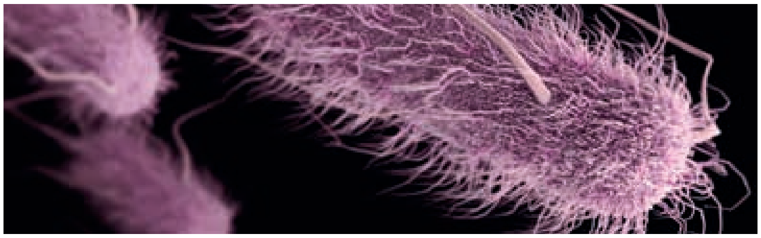





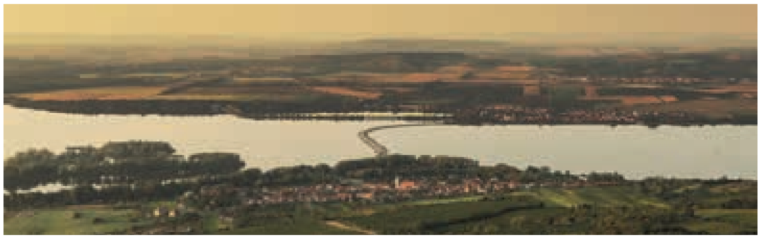

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# Dear readers,

While the summer holidays are slowly coming to an end, you will certainly appreciate information that may be useful after the holidays. The topics that you will find in this issue relate to areas that are a priority for the European Union and thus appear in most of its strategies, whether they deal with wastewater recycling, drinking water, or waste. I am sure, that just like me, you will appreciate the article presenting the results of the citation analysis of the VTEI journal. Citations are one fragment of the mosaic of important parameters that move it step by step towards the target of the main stage of its development, which is to be entered into the Scopus database.

Exceptionally, none of the articles in this issue deal with climate change; at the same time, several interesting conferences on this topic were held in June organized by Prague City Hall, the Ministry of the Environment, and the Ministry of Science, Research and Innovation, while the topic also permeates the conferences organized on the occasion our EU Council Presidency. Even the weather seemed to confirm climate change – torrential rains with hail, tropical days and nights, and the occasional tornado and flood.

Once again, the summer has had the usual drought and storms, but since it is a holiday season for the scientific and research community – unlike farmers – I can only wish you, our loyal readers, a pleasant second half of the summer, enriched by the collection of practical knowledge that, in the autumn months, you can successfully use in new projects. To remind us of the reality of life and to appreciate a quiet holiday and the opportunity to freely conduct research, we have included an interview with our new colleague from Ukraine, Dr. Yelizaveta Chernysh, who before the war worked at the State University in the city of Sumy.

Ing. Tomáš Urban
Director of TGM WRI, p.r.i.

# Bacteria from the family *Enterobacteriaceae* in reused water and their antibiotic susceptibility

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**Keywords:** reused water — *E. coli* — total coliforms — ATB resistance

## SUMMARY

This article evaluates the presence of bacteria from the *Enterobacteriaceae* family (i.e. total coliforms, thermotolerant coliforms, and *Escherichia coli* (*E. coli*) in different types of reused water (grey water, rain water, and reclaimed water from urban water features) and problems with their detection (especially sensitivity and specificity of cultivation methods). The species composition of coliform bacteria in purified grey water with their antibiotic resistance are presented. As expected, the greatest antibiotic resistance was found in penicillin derivatives (ampicillin and amoxicillin clavulanate), which accounted for 32 % of the *E. coli*/*Shigella* group. Resistance to other studied antibiotics was demonstrated in 7–12 % of all coliform strains. The most resistant strains were isolated from medical facilities. Only one strain (*E. coli* from a medical facility) was resistant to meropenem.

## INTRODUCTION

*Escherichia coli* (*E. coli*) is the most important indicator of faecal contamination and has practically replaced previously used coliform bacteria (or thermotolerant/faecal coliform bacteria) which, unlike *E. coli*, may not always have faecal origin and some representatives may reproduce normally in the aquatic environment. *E. coli* is thus a key microbiological indicator in most regulations, which include requirements for water hygienic safety. This is no different in the case of reused water. During our search of foreign regulations concerning requirements for the quality of reused water and rainwater when used indoors, we found that 12 of the 14 regulations monitor *E. coli*, 4 regulations also prescribe monitoring for coliform bacteria, and 3 require monitoring of faecal (thermotolerant) coliform bacteria either as the sole microbiological marker or together with *E. coli*. Matějů et al. [1] compiled an overview of 22 standards and legal regulations to regulate water reuse, including irrigation water. Each of these regulations sets out requirements for microbiological indicators, represented by total coliforms, thermotolerant coliforms, and *E. coli*. Interestingly, *E. coli* (59 %) is most often mentioned (i.e., 13 times), followed by coliform bacteria and faecal (thermotolerant) coliforms (seven times in total). Of these, a combination of *E. coli* and coliform bacteria, and once a combination of coliform and faecal (thermotolerant) coliform bacteria, are mentioned four times. Occasionally, the term "thermotolerant *coli*" appears in a text, discussion, or draft regulation, which is misleading and probably refers to a group of thermotolerant coliforms. As such, *E. coli* is thermotolerant, but this property is the first to be lost in an aqueous (non-physiological) environment.

The subject of this article is not to evaluate the significance of these indicators in reused water, but to show their heterogeneity in this environment and methodological difficulties in their determination. These are mainly due to the complex, highly active, and heterogeneous matrix (high content of the accompanying microflora). In order for the results obtained to be relevant (i.e., correct and accurate), the methods used must be sufficiently sensitive and selective, which is often a big problem for such active matrices. We have already addressed this issue in the case of natural bathing water [2], where the most suitable method for the determination of *E. coli* proved to be the financially demanding MPN (most probable number) procedure according to ČSN EN ISO 9308-2.

## METHODOLOGY

### Samples and their collection

From June 2020 to December 2021, in compliance with the applicable rules for sampling (ČSN EN ISO 5667-1, ČSN EN ISO 5667-3, ČSN EN ISO 19458), samples of grey water (residential buildings, public buildings, and medical facilities), rainwater (residential buildings and public buildings) and reused water from urban water features were collected in sterile sample boxes. The samples were transported under constant cooling (5 ± 3 °C) and processed within a maximum of 18 hours after collection.

### Methods of analyses

Methods for culture determination were used according to the following standards and procedures:

- ČSN EN ISO 9308-1 – Chromocult Coliform Agar (Merck), membrane filtration (filters with a porosity of 0.45 µm), cultivation for 24 hours at 36 °C.
- ČSN EN ISO 9308-2 (Colilert/Quanti-Tray), cultivation for 18 hours or 24 hours (depending on the type of test) at 36 °C.
- ČSN 75 7835 – m-FC Agar (Merck), membrane filtration (filters with a porosity of 0.45 µm), cultivation for 24 hours at 44 °C.

— Optimized method for *E. coli* determination on chromogenic TBX medium (Merck), membrane filtration (filters with a porosity of 0.45 µm), cultivation for 24 hours at temperatures of 36 °C or 44 °C, possible pre-cultivation on selective medium TSA/CA or TBX for 4 hours at 36 °C.

## Determination of antibiotic resistance

145 strains of gram-negative bacteria from the family *Enterobacteriaceae*, belonging to the group of coliform bacteria, were isolated from purified grey water (11 localities). The strains were purified and identified by MALDI-TOF and tested for antibiotic susceptibility by disk diffusion according to the European Committee on Antimicrobial Susceptibility Testing, version 7.0 of January 2019, so-called EUCAST [3] (*Fig. 1*). If a low number of colonies (less than five) were detected in the sample, all were tested; otherwise, five to eight colonies were selected, preferably of different appearance. The strains were tested for antibiotics from the Oxoid company (disc content in parentheses): ampicillin (10 µg); amoxicillin-clavulanic acid (30 µg); cefotaxime (5 µg); cefepime (30 µg); ceftazidime (10 µg); meropenem (10 µg); ciprofloxacin (5 µg) and gentamicin (10 µg).

# RESULTS AND DISCUSSION

## Representation of *E. coli* among coliform bacteria in various types of water (not only reused)

Like other coliform bacteria, *E. coli* is a member of the *Enterobacteriaceae* family; however, unlike other species, it does not survive in the aquatic environment for long periods of time. The percentage of *E. coli* among coliform (or thermotolerant coliform) bacteria may indicate the severity of direct faecal contamination and, in part, the level of organic contamination. *Tab. 1* shows the different percentages of *E. coli* among coliform bacteria in the different types of reused water we monitored. Only the results of sampling in 2021 are given, as all these analyses were performed by the method according to ČSN EN ISO 9308-2, and are therefore comparable. For statistical purposes, values above the working range > 2 419.2 were replaced by 3 750 and values > 4 838.4 by 7 500 MPN/100 ml.

As expected, the most identified representatives of *E. coli* among coliform bacteria were found in raw grey water (31 %). However, these results are also the least accurate, as most results were above the working range of the method. Significantly less *E. coli* was found in treated grey water (8.1 %). The second highest incidence of *E. coli* was found in urban water elements, which is logical because direct faecal pollution can also occur there. In contrast, the least *E. coli* among coliform bacteria (2.6 %) was determined in rain water, where the absolute numbers were also low. For comparison, e.g. in surface water (the Labe and Vltava rivers), *E. coli* was found among coliform bacteria in 24.7 % of cases [4]. Here, however, the indicators were not determined by the method according to ČSN EN ISO 9308-2, but according to ČSN 75 7837 (Endo agar), or ČSN 75 7835 (m-FC with β-D-glucuronidase). A change in the method for determining coliform bacteria, in this case fermentation of lactose versus β-D-galactosidase activity, has led to a broader understanding of the group of coliform bacteria, which currently includes significantly more species than in the past.

## Methods tested for determining coliform bacteria and *E. coli* in reused water

The problem of detection – especially of the species *E. coli* in water with rich accompanying microflora – is the fact that determination is usually performed in parallel with detection of coliform bacteria on a very sensitive medium. Detectors (membrane filters or Petri dishes) tend to be overgrown not only with the accompanying microflora, but also with coliform bacteria, which discriminates against *E. coli* (usually in a significant minority), so that its colonies cannot grow properly on the medium. Dilution of the samples will not help in this case because *E. coli* is diluted first (*Fig. 2*), which makes it possible to obtain a false negative result, or the limit of detection is significantly increased. Statistical evaluation of these types of results was not performed in our survey because some methods were quickly excluded after analyses of several series of samples as methods unsuitable for a given matrix.

Another possibility is to use m-FC medium (ČSN 75 7835) and determine either thermotolerant coliform bacteria (indicator as such) or identify *E. coli* by

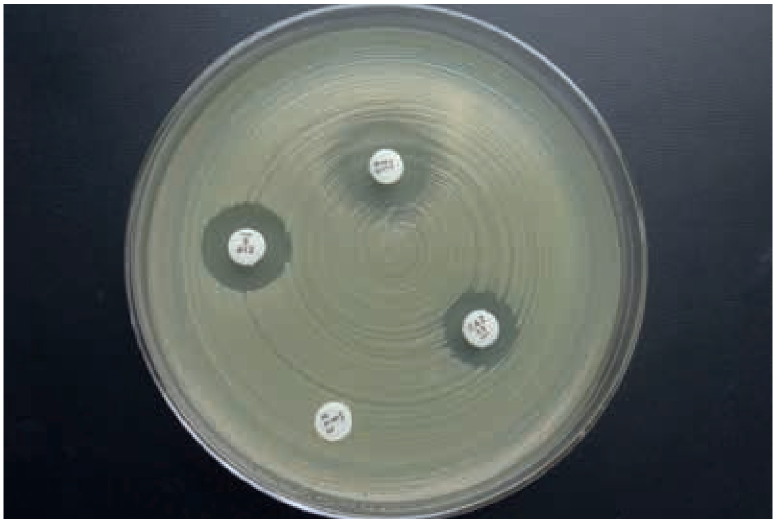


Fig. 1. Disc diffusion method – disks impregnated with the antibiotics are placed in a Petri dish with Mueller Hinton medium inoculated with the test strain; based on the size of the growth inhibition zone around the disc, susceptibility/resistance to a given antibiotic is determined.

*Tab. 1. E. coli among total coliform bacteria in different types of reused water*

| Type of recycled water | Number of analyses for calculation | Number of zero *E. coli* findings | Average percentage of *E. coli* among coliform bacteria |
|---|---|---|---|
| Urban water elements | 67 | 12 | 19.3 % |
| Rainwater | 45 | 8 | 2.6 % |
| Raw grey water | 12 | 3 | 31 % |
| Treated grey water | 14 | 16 | 8.1 % |

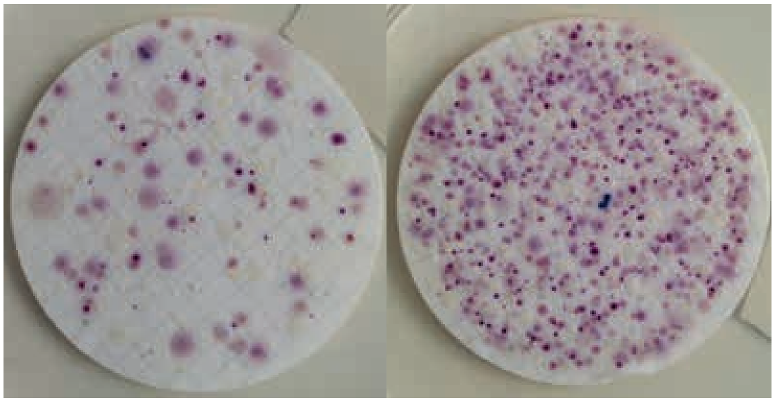


Fig. 2. Detection of *E. coli* according to EN ISO 9308-1 (CCA medium) from grey water matrix – presence of *E. coli* (blue and violet blue colonies) in higher volume is apparent, but difficult to calculate in the growth of coliform bacteria (rose/pink colonies); at higher dilutions it can no longer be detected

subsequent detection of the enzyme β-D-glucuronidase. The first option would probably be more appropriate as m-FC medium is extremely selective (with low productivity below 50 %) and the cultivation temperature of 44 °C is very high; however, the results of *E. coli* determinations are often underestimated by this method [2]. Although, in most cases, the accompanying microflora is eliminated, in extremely microbially loaded samples (which contain a large number of proteolytic bacteria) it can increase and, in this case, sometimes interfere with acid-base reactions, on which this medium is based. The result is the formation of red rather than blue colonies (proteolytic bacteria can produce large amounts of ammonia, and therefore this alkaline environment may not allow the expression of acid reaction products formed after lactose fermentation).

The MPN method according to ČSN EN ISO 9308-2, which is sufficiently sensitive and selective and has a working range of three orders of magnitude, proved to be the most suitable standardized method so far. We also use this method by default in our analyses. However, it also has certain disadvantages, which is primarily its cost, and then the necessity to purchase a relatively expensive Quanti-Tray system (which is why many laboratories do not have it). Last but not least, this method produces an enormous amount of infected plastic waste. Therefore, we looked for another way to determine *E. coli* in reused water.

In 2019, some Croatian authors [5] published a proposal for an optimized method for the determination of *E. coli* in bathing water on TBX medium (Trypton Bile X-Glucuronide). TBX is a chromogenic medium where *E. coli* is detected by β-D-glucuronidase enzyme activity and grows in the form of turquoise colonies (all other bacteria, including other species of the *Enterobacteriaceae* family, grow as colourless colonies). For the determination of *E. coli* from natural water, pre-cultivation of inoculated dishes or membrane filters is used, lasting 4 hours at 36 °C, either on nutrient-rich non-selective medium or directly on TBX medium. The mentioned authors [5] used MMGA (Minerals Modified Glutamate Agar) for pre-cultivation, while we used tryptone soy agar (TSA) or Columbia agar (CA) as well as TBX. Our preliminary results have shown that the optimized method is promising [6] (*Fig. 3*). The accompanying microflora was sufficiently suppressed and the number of *E. coli* determined by cultivating on solid medium was comparable with the results obtained by MPN method when cultivating in liquid medium according to ČSN EN ISO 9308-2 (Quanti-Tray), which is the same principle of determination (β-D-glucuronidase).

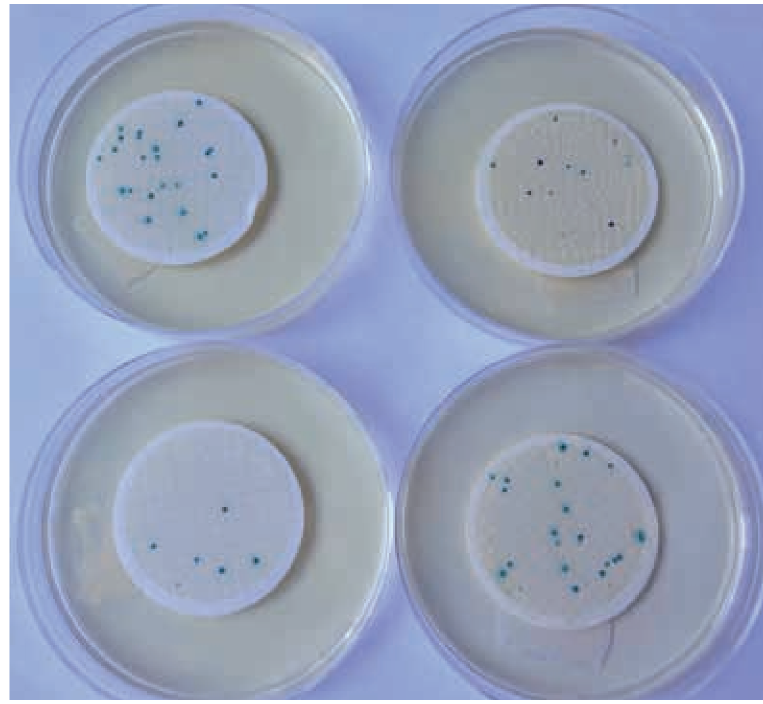


Fig. 3. *E. coli* on TBX medium (top left: 4 hrs cultivating at 36 °C, then for 20 hrs at 44 °C; top right: cultivating for 24 hrs at 36 °C; bottom left: incubation for 24 hrs at 44 °C; bottom right: cultivation on CA for 4 hrs at 36 °C, then for 20 hrs at 44 °C on TBX)

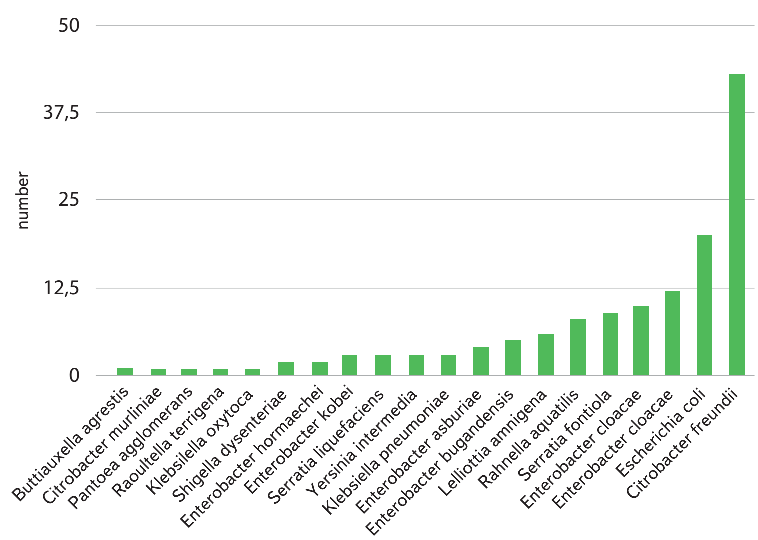



Fig. 4. List of isolated and identified coliform bacteria species

## Coliform bacteria isolated from purified grey water and their antibiotic resistance

As already mentioned, 145 strains of bacteria from the family *Enterobacteriaceae*, belonging to the group of coliform bacteria, were isolated and identified from purified grey water (11 localities). These strains were further tested for possible antibiotic resistance. The strains achieved an average score of 2.29 when identified on MALDI-TOF, which means highly probable identification of the species. The species composition of isolated strains is shown in *Fig 4*. However, some species, although thus "accurately" identified, belong to broader taxonomic groups (*E. coli/Shigella*, *Enterobacter cloacae* complex, *Klebsiella oxytoca/*

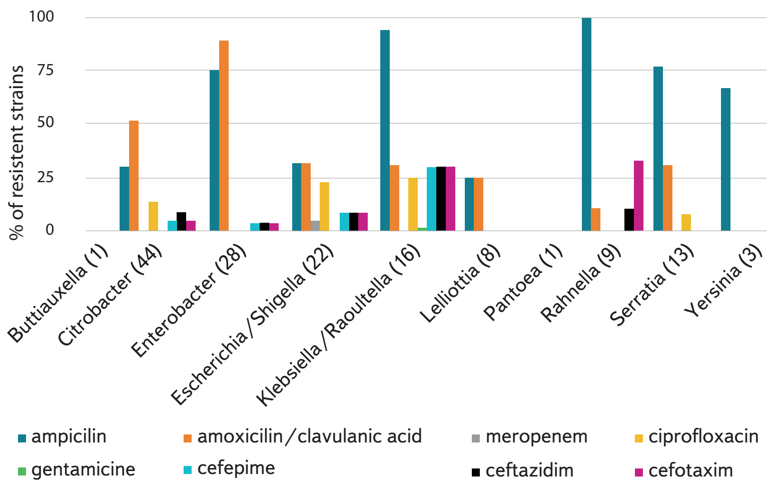



Fig. 5. Percentage of resistant strains in individual genera/taxonomic groups of coliform bacteria; the number of isolated and tested strains of the relevant genus/group is given in brackets after the genus name

/*Raoultella terrigena*, etc.), and their distinction is therefore rather theoretical. The assessment of antibiotic resistance is thus presented at the level of these groups or genera.

Based on data from the literature search and from the EUCAST clinical breakpoint table [7], a set of antibiotic disks suitable for resistance testing in coliform bacteria (bacteria from the *Enterobacteriaceae* family) was selected. The final set includes penicillins (ampicillin, amoxicillin-clavulanic acid), cephalosporins (cefotaxime, cefepime and ceftazidime), carbapenems (meropenem), fluoroquinolones (ciprofloxacin), and aminoglycosides (gentamicin). Tetracycline has not been tested because EUCAST does not provide interpretation criteria for this group of bacteria, so-called clinical breakpoints, which are the averages of zones according to which strains are categorized as sensitive or resistant.

As expected, the highest resistance was found for penicillin derivatives (ampicillin and amoxicillin-clavulanic acid). However, some genera of bacteria are naturally resistant to these penicillins [8]. Of the strains we isolated, in the case of ampicillin, it was mainly the genera *Citrobacter*, *Enterobacter*, *Klebsiella*, and *Raoultella*; in the case of amoxicillin-clavulanic acid it was *Citrobacter freundii* and the genus *Enterobacter*. From the point of view of our research, *E. coli*, which does not have a natural resistance to these antibiotics, is especially important. Of the 22 *E. coli* strains tested (along with *Shigella dysenteriae*), 32 % were resistant to both ampicillin and amoxicillin-clavulanic acid. Our results are relatively consistent with the literature data, according to which ampicillin resistance was found in 38 % of *E. coli* strains from wastewater [9] and in 18 % of *E. coli* strains isolated from wastewater and sludge [10].

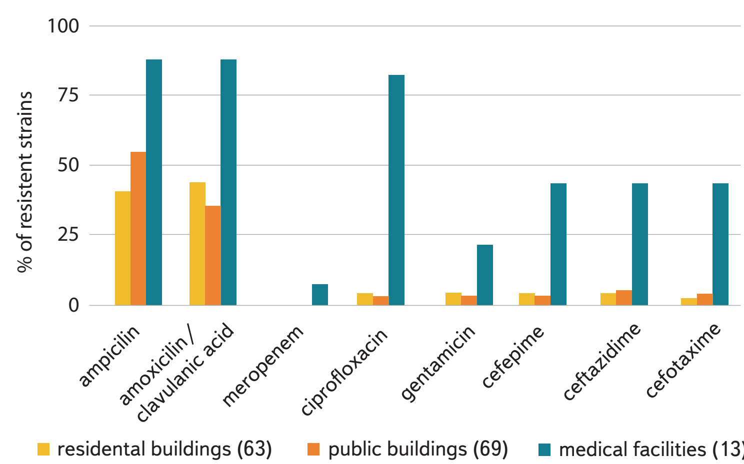
Meropenem resistance was demonstrated in only one *E. coli* strain from a medical facility (i.e., 0.7 %), while 11.7 % of all coliform strains were resistant to ciprofloxacin, 9 % to gentamicin, 7 % to cefepime, 9 % to ceftazidime, and 9 % to cefotaxime. For comparison with other studies worldwide [9], 6 % of ciprofloxacin-resistant *E. coli* isolates from wastewater were found. Strains of bacteria from the family *Enterobacteriaceae* (especially the genera *Enterobacter* and *Citrobacter*) resistant to gentamicin, ciprofloxacin, meropenem, ceftazidime, and amoxicillin-clavulanic acid have also been isolated from well water in Slovakia [11].

Demonstrated resistances in individual genera of bacteria or monitored types of buildings with reused water are shown in *Fig. 5* and *6*. The highest level of antibiotic resistance was found in strains isolated from a medical facility. Unfortunately, we have the smallest number of these strains. Fourteen strains (9.7 %) were resistant to three or more tested antibiotics, so they were multi-resistant strains.

## CONCLUSION

Among coliform bacteria, *E. coli* occurs in reused water and rainwater from 2.6 % (rainwater) to 31 % (raw grey water). Due to the high content of the accompanying microflora (especially in grey water), the method according to ČSN EN ISO 9308-2 is currently the most suitable method for *E. coli* detection. For the future, there seems to be a promising optimized method for the determination of (only) *E. coli* (with a four-hour resuscitation step) on TBX medium.

Using the MALDI-TOF method, 19 species of coliform bacteria occurring in purified grey water were identified and tested for antibiotic susceptibility. In terms of antibiotic resistance, the highest was, as expected, identified for penicillin derivatives (ampicillin and amoxicillin-clavulanic acid), at 32 % in the *E. coli/Shigella* group. Resistance to other monitored antibiotics was demonstrated in 7–12 % of all strains of coliform bacteria. The most resistant strains were isolated from medical facilities. Only one *E. coli* strain isolated from water from a medical facility was resistant to meropenem. These results are consistent with the results of other experts who have isolated bacteria from different types of water (wastewater, sludge, wells) [9–11].



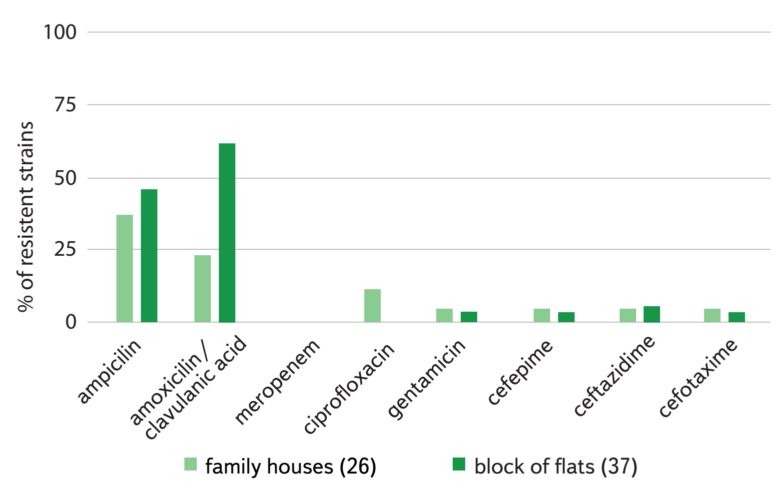




Fig. 6a (top) and 6b (bottom). Percentage of resistant strains (without genus distinction) according to isolation from different types of localities; the number of isolated and tested strains is given in brackets after the type of locality; we consider family houses to be buildings with a maximum of two flats.

Photo: 123RF.com

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# River ferries on old topographic maps

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**Keywords:** modern age — military mapping — river — ferry — Czechia


## SUMMARY

Medium and large rivers were a major obstacle to historic trade routes and trails. River ferries were one of the main ways to cross them, so their sites were considered points of strategic importance. Using old topographic maps from Austrian military mapping from 1763–1768, 1836–1852, 1876–1880, Prussian military maps from 1825 and 1877, and Czechoslovak military maps from 1953–1957, we systematically located ferries throughout the current territory of Czechia. Map keys from individual mappings were also analysed to examine how ferries are depicted on these maps. Based on the study of old topographic maps, a geographical database was created with the location of individual ferries, including the period in which the river ferry was registered. A total of 514 historical ferries were recorded on old topographic maps from military mapping throughout Czechia; another 28 ferries were identified from other available, more detailed, map sources.


## INTRODUCTION

Large rivers embody a natural landscape barrier that has always had a significant influence on the management of transport networks. Sections suitable for safe crossing of such a barrier were important strategic and trading places, and therefore are used in history as fixed points in the reconstruction of the course of old roads and trails [1]. Even in the first half of the 19th century, stone bridges were rare; some wooden bridges were unmaintained and dangerous, so fords were one of the possible ways of crossing rivers. On larger rivers in sections with greater depth, it was already necessary to provide transport in another way, usually by river ferry or boat. The operation of ferries was originally part of the landowners' privileges, and a fee was collected from the ferryman for the transport of people, goods, and cargo.

In 1870, the Imperial Water Act was adopted, by which the operation of ferries became a licensed business [2] and three regional laws for individual administrative territories. The Czech Land Act No. 71/1870 applied to Bohemia on how to use, collect and protect against water; for Moravia, the Moravian Land Act No. 65/1870 on the use and operation of waters and protection against them; and for Silesia, the Silesian Land Act No. 51/1870 on the use and operation of waters and protection against them. The Moravian and Silesian water laws differed from the Czech law only in some details [3].

With the gradual development of technical knowledge and construction technologies, bridges became the dominant option for crossing watercourses, and ferries were preserved only in places where bridge construction was not possible for technical or economic reasons. In Czechia, ferries are currently also operated on some more important water reservoirs. In urban areas in particular, ferries currently serve as part of public transport [4, 5], which is not only about preserving a certain tradition in the transport system, but also about the practical effect of reducing transport time for daily commuting and, at the same time, as an attraction in the tourism industry. Ferries thus compensate for the lack of bridges that would facilitate the movement of passengers between specific destinations on opposite banks of rivers. Tourist demand is another driving force that is crucial to maintaining the operation of river ferries, as they offer passengers a unique waterscape experience that is outside of today's dominant forms of transport [6, 7].

Old topographic maps are a valuable source of information about the state of the then landscape, and, simultaneously, can be applied in geographical, historical, and landscape-ecological research. In Europe, topographic maps are usable from the mid-18th century, when the first medium-scale maps (around 1 : 25 000 to 1 : 30 000) began to appear. Since the mid-19th century, topographic maps achieved a relatively solid positional accuracy of around 25 m due to high-quality cartographic and geodetic foundations [8]. These maps are used in a wide range of research areas; in the case of rivers and water bodies, the historical connections of the development of water bodies and ponds [9], historical development of the river network [10], and historical identification and registration of water management objects [11] are most often examined. Systematic identification and registration of all sites with ferry operations has not yet been published in the Czech Republic. Some historical works dealt with specific sections of rivers, while their methodology for the identification of ferries was mainly based on archival sources [12, 13]

Due to the relatively simple equipment required for ferry operation, which consists of the vessel itself, two embarkation piers or entrances into the water, and a guide rope, ferries can easily come and go (*Fig. 1*). Slight changes in the ferry location can thus be caused by morphological changes in river beds or banks [14], or by changes in the settlement structure of villages and towns.

The main objectives of this article include:

— researching the method and form of displaying river ferries on old topographic maps of individual military mapping,
— identification of all ferries recorded on old topographical maps on the area of the present-day Czechia and the creation of a map database of these sites,
— verification of the suitability of old topographical maps as one of the essential sources for recording the historical ferry sites.

## METHODOLOGY

The identification and registration of ferries was carried out using map sets of old topographical maps in a GIS environment. The following map files were used:

— 1st Austrian Military Mapping 1 : 28 800 (1763–1768)
— 2nd Austrian Military Mapping 1 : 28 800 (1836–1852)
— 3rd Austrian Military Mapping 1 : 25 000 (1876–1880)
— Prussian military maps 1 : 25 000 (1825, 1877)

Fig. 1. A ferry for motor vehicles on the Elbe river in Dolní Žleb

— Czechoslovak military topographic maps 1 : 25 000 (1953–1957)

The maps of the 1st Austrian mapping were created for the territory of today's Czechia in stages for the individual historical Czech lands (Silesia 1763, Bohemia 1764–1767, Moravia 1764–1768). The relatively poor positional accuracy of these maps is caused by insufficient cartographic foundations; the average deviation of georeferenced maps reaches up to 300 m.

The maps of the 2nd Austrian military mapping were created on the territory of Moravia and Silesia between 1836 and 1852, and on the territory of Bohemia between 1842 and 1852. These maps are based on the geodetic network, used in the surveying of cadastral maps; the positional accuracy is 25–30 m.

The maps of the 3rd Austrian military mapping were created on our territory between 1876 and 1880. These maps already capture the boom of industry, the construction of railway lines, road networks, and the dynamic growth of settlements. Approximately two-thirds of the map sheets are available in the original colour version; the remaining third has been preserved in black and white.

Czechoslovak topographic military maps from 1953–1957 were, after more than 80 years, the only complete cartographic set that was completed on the entire territory of the current Czechia. It is a positionally accurate cartographic work that used a uniform system of mapping and sheet layout for the socialist countries in Europe.

In the area of Hlučínsko, which was not part of Austrian Silesia in the 19th century, cartographic sources of Prussian provenance were used, namely military topographic maps from 1825 and 1877. These maps were georeferenced with a geodesic accuracy of 25 m.

The Basic Database of Geographical Data (ZABAGED) of the Czech Office for Surveying, Mapping and Cadastre was used to identify the ferries currently operating in Czechia. These data were verified on the basis of information from the State Navigation Administration.

Other auxiliary cartographic and archival sources were also used to identify the ferries; for example, detailed 1 : 10 000 topographic maps from 1957–1971, which are not yet available in a georeferenced form for the entire Czech Republic, reambulated maps from the 1930s and 1940s in 1 : 25 000 scale, 1 : 5 000 derivative state map taken since 1955, publicly available aerial photographs from the 1930s and 1950s. The location of the objects was also verified on the basis of current aerial photographs and basic maps at a scale of 1 : 10 000.

First, the map keys for individual periods were analysed, then the structure of the ferry database was designed, and in the last stage, vectorization was carried out using specific maps from individual periods.

The ferries were mapped according to the importance of the watercourses, always from the confluence or the border of the Czech Republic to the source area. During the identification of ferries, specific watercourses were monitored based on expert knowledge of their territory and width, presented in current and old topographical maps. Ferries operating on water reservoirs are registered at the watercourses that feed these reservoirs.

In addition to the use of classic map markers, toponyms which denoted the ferry in the German and Czech languages were used. Ferries were considered identical in the historical cross-section if the objects were located at a distance of less than 50 m. If the distance between ferries in different time periods was greater than 50 m, these sites were recorded separately. For the period 1953–1957, the location of the ferries was specified using old aerial photographs.

Based on the above-mentioned process, a database of river ferries in Czechia was prepared in the form of a point layer in the S-JTSK coordinate system; this includes the name of the ferry, location by the river, cadastral territory, data on latitude and longitude, existence or non-existence of the ferry in time periods according to mapping, and information about auxiliary resources.

*Tab. 1. Cartographic signs for ferries in the legends of old topographic maps*

| | Period | | | | |
|---|---|---|---|---|---|
| **Ferry type** | **1763–1768** | **1836–1852** | **1876–1880** | **Prussia 1877** | **1953–1955** |
| Pedestrian ferry |   |  |  |  |  |
| Horse ferry |  |  |  |  | |
| Cargo ferry |  |  |  | |  |
| Floating bridge | n/a |  |  |  | |
| Steam powered ferry | n/a | n/a |  |  | n/a |

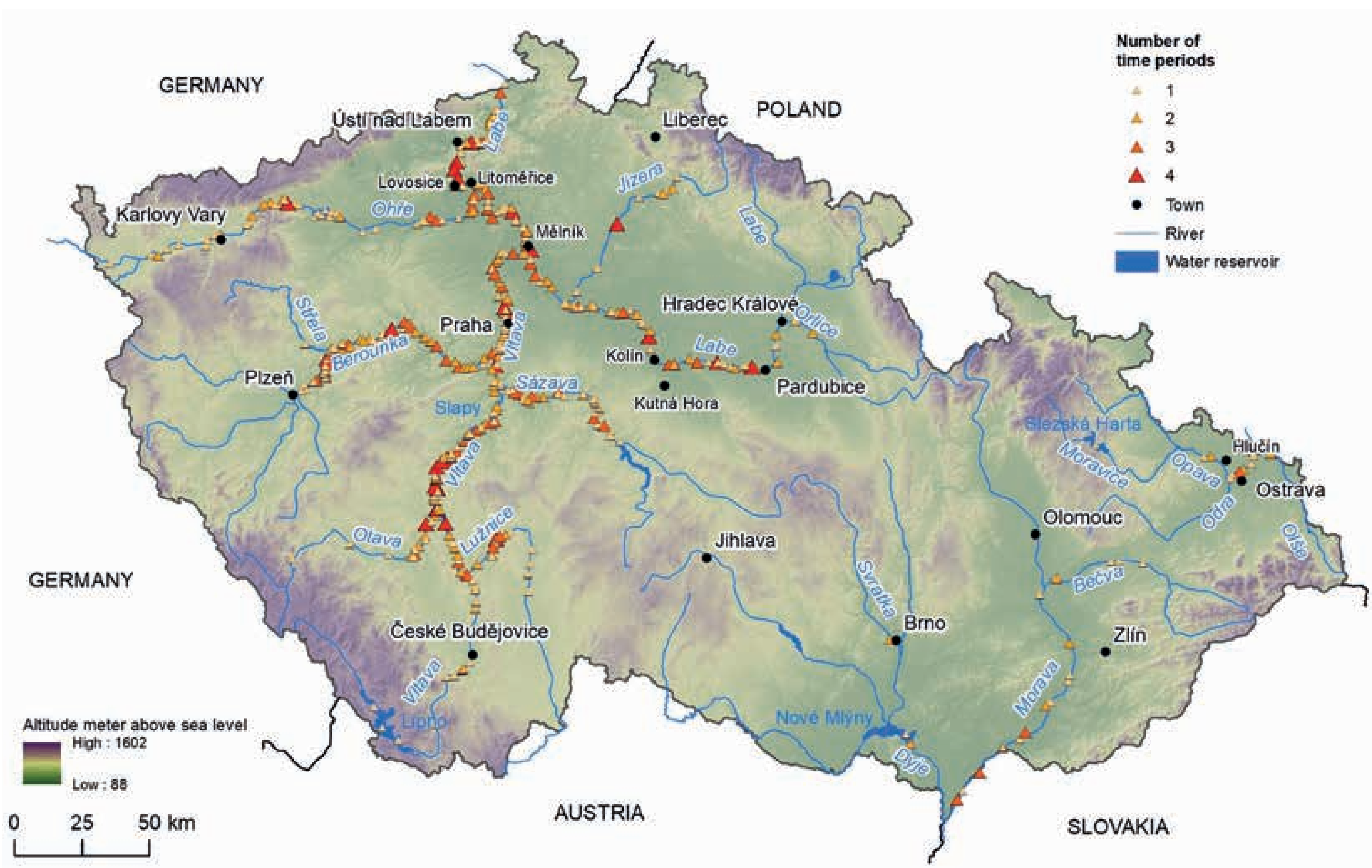


Fig. 2. Number of periods of ferry operation in Czechia based on the study of old topographic maps, see *Tab. 2*

# RESULTS

## Cartographic analysis of the way ferries are depicted on old topographical maps

Based on the analysis of the map keys of the individual mappings, the following types of ferries were identified: pedestrian ferries (Austrian military mapping: Überfuhr für Menschen, Prussian military mapping: Kahn-Fähre), horse ferries (Austrian military mapping: Überfuhr für Pferde), cargo ferries (Austrian military mapping: Überfuhr für Wagen). A specific map mark is the so-called floating bridge (Austrian military mapping: Fliegende Brücke), which consists of the firm anchoring of a ship or ferry in the middle of the river and the fixation of the vessel on a rope *(Tab. 1)*. The maps of the 3rd Austrian Military Mapping also contain all three categories of ferry types (Überfuhr), including designations for steam-powered ferry (Dampffähre), and railway ferry (Eisenbahntrajekt). This legend is universal for the entire territory of the former Austria-Hungary; however, both of the latter types of ferries did not occur in the territory of today's Czechia.

*Tab. 2. Numbers of ferries per river identified in each time period*

| | Period | | | | | |
|---|---|---|---|---|---|---|
| **River** | **1763–1768** | **1836–1852** | **1876–1880** | **1953–1955** | **2020** | **Total** |
| Bečva | | | 1 | 5 | | 5 |
| Berounka | 7 | 55 | 38 | 15 | 3 | 66 |
| Dyje | | 1 | 1 | 1 | | 2 |
| Jizera | 1 | 3 | 6 | 3 | 1 | 9 |
| Labe | 30 | 63 | 74 | 43 | 10 | 129 |
| Lužnice | 10 | 8 | 4 | 5 | | 15 |
| Morava | 6 | 6 | 8 | 4 | | 15 |
| Moravice | | | | | 1 | 1 |
| Odra | 1 | 7 | 2 | | | 7 |
| Ohře | 12 | 28 | 26 | 5 | 1 | 51 |
| Olše | | 2 | 1 | | | 2 |
| Opava | | 2 | 1 | | | 2 |
| Orlice | | 3 | 1 | | | 3 |
| Otava | 5 | 11 | 7 | 4 | | 15 |
| Sázava | 4 | 10 | 23 | 12 | 1 | 34 |
| Střela | | | 1 | | | 1 |
| Svratka | 1 | 1 | | | | 1 |
| Vltava | 49 | 60 | 96 | 31 | 16 | 156 |
| **Total** | **126** | **260** | **290** | **128** | **33** | **514** |

## Spatial distribution of historical ferry sites

The database currently contains a total of 542 historical ferry sites on the territory of today's Czechia, of which 514 come from identification on maps created as part of individual military mapping. The remaining ferry sites were identified only from auxiliary sources without actually appearing on military topographical maps. An overview of the number of ferry sites by watercourses for each time period is shown in *Tab. 2*.

The highest number of ferries was identified on military maps from 1876–1880, with more than half (56.4 %) of the total number of ferry sites in operation during this period. A similar figure (50.6 %) was also recorded in the earlier period 1836–1852. In terms of other time periods, the numbers of identified ferry sites were significantly lower, with approximately the same number of sites recorded on the 1763–1768 and 1953–1955 maps; however, only 33 (6.4 %) of them currently have a ferry in operation. Ferries were identified on a total of 18 different watercourses. The significantly highest number of sites were discovered on the two largest watercourses, i.e. the Elbe and Vltava (55.4 %); a significant number of ferries were also recorded on the Berounka and Sázava. No other river was found to have more than 15 ferry sites. *Fig. 2* shows a clear spatial imbalance in the distribution of ferries within Czechia. The majority of ferries

*Tab. 3. Stability of recognized sites per river: the numbers of time periods related to the counts of ferries on the maps*

| | Number of periods | | | | | |
|---|---|---|---|---|---|---|
| **River** | **1** | **2** | **3** | **4** | **0 *** | **Total** |
| Bečva | 4 | 1 | | | | 5 |
| Berounka | 30 | 22 | 12 | 2 | 4 | 70 |
| Dyje | 1 | 1 | | | | 2 |
| Jizera | 6 | 2 | | 1 | | 9 |
| Labe | 72 | 32 | 16 | 9 | 6 | 135 |
| Lužnice | 8 | 3 | 3 | 1 | 2 | 17 |
| Morava | 9 | 3 | 3 | | | 15 |
| Moravice | 1 | | | | | 1 |
| Odra | 5 | 1 | 1 | | | 7 |
| Ohře | 36 | 10 | 4 | 1 | 1 | 52 |
| Olše | 1 | 1 | | | | 2 |
| Opava | 1 | 1 | | | | 2 |
| Orlice | 2 | 1 | | | | 3 |
| Otava | 8 | 4 | 1 | 2 | | 15 |
| Sázava | 24 | 4 | 6 | | 3 | 37 |
| Střela | 1 | | | | | 1 |
| Svratka | | 1 | | | | 1 |
| Vltava | 93 | 39 | 15 | 9 | 12 | 168 |
| **Total** | **302** | **126** | **061** | **025** | **028** | **542** |

* Sites registered only on the basis of auxiliary sources, without occurrence in military mapping.

Fig. 3. The Oseček ferry on the Elbe river has been operating (with a short break) since 1836

were located in the western part of the country (the Elbe basin), while only 35 (6.8 %) were located in the eastern part (the Morava and Odra basins).

During the entire research, we did not identify a ferry that was present on all the maps in all five examined periods (*Tab. 3*). Only 4.6 % of ferries (25) were recognized in four time periods, mostly on the Elbe and Vltava rivers (9 sites each). Oseček on the Elbe river, which is still in operation today (*Fig. 3*), can be cited as one of the examples of a ferry recorded on four topographical maps. A substantial number (55.7 %) of the ferries in the database appeared in only one of the periods and was no longer present in the others. As for important rivers (15 or more ferries), the largest representation of sites with ferries can be found on the Ohře river (69.2 %).

## Verification using navigation charts and water books

The explanatory power of topographic maps is influenced by various aspects, whether objective (i.e., based on the scale of the map, the map key, and its designation) or subjective (which includes the creator of the map responsible for recording relevant features in the landscape). The aim of this chapter was to at least partially assess the reliability of the applied research methodology by comparison with other sources indicating the existence of ferries in similar time periods and territorial units. Due to the lack of accurate sources in previous periods, verification was only feasible for the period between 1953 and 1955, when two possible alternatives were recognized representing sources of information that were not based in any way on topographic maps.

## Navigation charts for the Elbe between Lovosice and Kolín and for the Vltava beyond Prague

Valuable historical material are navigation charts *(Fig. 4)*, which were provided by the National Archives of the Czech Republic [14]. The maps contain data and kilometre locations of operationally important factors facilitating safe navigation on navigable rivers, while the last update took place at the end of 1950. We used these chart to compare results from the Elbe area between Litoměřice and Kolín, and from the middle and lower part of the Vltava. The area of the middle Povltaví region underwent major changes between 1950 and 1955, when large-scale water structures were built, including Slapy reservoir, at the time the largest reservoir in the Czech Republic [16]. The navigation chart relating to this area was thus no longer relevant for verification.

The Elbe navigation chart covers 83 km of the watercourse between Mělník and Kolín, and about 50 km from Mělník to Lovosice. The comparison on the lower Vltava was made for 44 km between Prague-Troja and the confluence with the Elbe near Mělník (navigable km 201 to 245). The results are shown in *Tab. 4*.

The agreement between the information coming from old topographic maps, on the one hand, and data from the navigational charts, on the other hand, was approximately 70 %, if we also take into account the time aspect. If only the location of the ferry sites were taken into account, the agreement reached more than 97 %. Only one of the ferries (2.2 %) was identified in the navigation charts, while it was completely missing in the database. However, we also came across a ferry shown on the topographic maps but not recorded on the navigation chart.

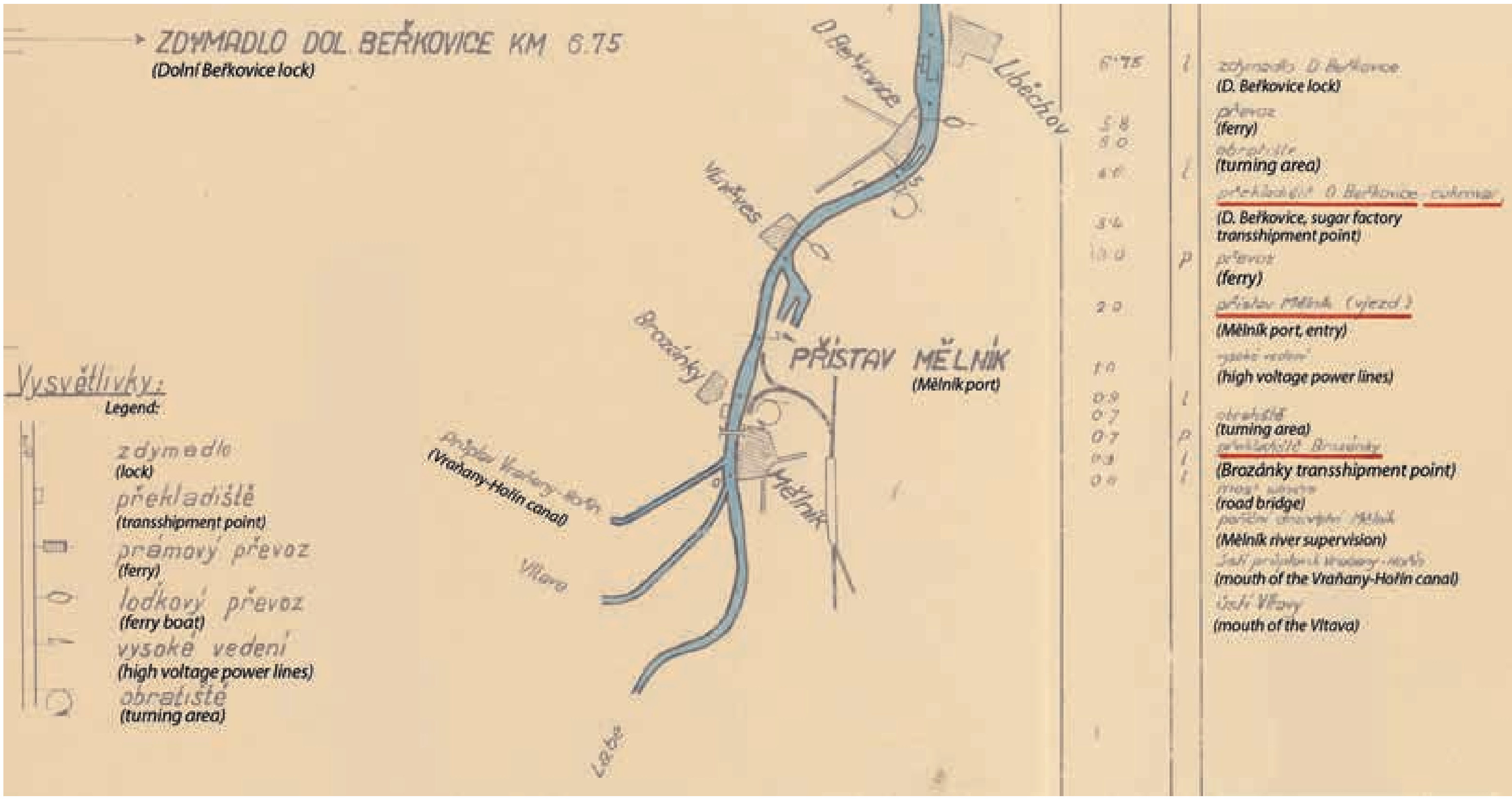


Fig. 4. An excerpt from a navigation chart and its legend (left bottom corner); the ferry signs are on the third and the fourth lines

## Water books for the Middle Posázaví region in the 1950s

Tihelka presented a map of ferries in the central Posázaví region for the Kutná Hora region in the last period of their existence in the middle of the 20th century [13]. He based his work on the official records of the so-called Water Books, which were kept at individual district offices and contain, among others, valid licenses for the operation of individual ferries. All sites mentioned in Tihelka's work were also identified using our methodology, but in many cases not with exact time determination. In the 1 : 25 000 maps, the ferries of Soběšín, Samopše, Sázava, Radvanice, and Rataje nad Sázavou, listed by Tihelka as having disappeared by 1952, 1953 or 1955, are missing. On the other hand, we identified the Střechov nad Sázavou ferry for the period 1953–1955. It is possible that these ferries were no longer actually operated at the time the military maps were issued, although they still had a valid license, as most of them are still marked on reambulated maps from the previous decade. However, a decade later, some of them even appeared on more detailed military maps at a scale of 1 : 10 000. In the same way, Tihelka also mentions the Ledečko ferry, which ceased to exist by 1956, but according to data from the Directorate of Roads and Highways of the Czech Republic (ŘSD), it was already replaced by a bridge around 1932.

# DISCUSSION

When examining the ways of depicting ferries on various old maps relating to the central European area, we found that ferries are depicted in different forms and that, at the same time, different categories of ferries can be distinguished in some periods. Criteria enabling such a distinction included, for example, the mode of transport (passenger or cargo), specific type of ferry (boat or barge) and, in the 20th century, parameters determining the carrying capacity of the ferry. A total of 542 ferries were identified in Czechia, of which 514 were found on old topographical maps. The most significant problems were related to the identification and location of ferries on the maps created by the 1st Austrian military mapping (1 : 28 800), where the poorer quality of some preserved copies and, above all, the rather problematic mapping methodology (which lacked precise geodetic foundations [17]) did not always guarantee sufficiently accurate location.

A set of very interesting data can be obtained from the results of the analysis of the temporal continuity of the existence of individual ferries. The results showed that no ferry was identified at one and the same place in all monitored

*Tab. 4. The numbers of ferries in the navigation charts and in the database of ferries*

| River section | A | B | C | D | E |
|---|---|---|---|---|---|
| Elbe (Mělník–Kolín) | 18 | 15 | 3 | 0 | 0 |
| Elbe (Mělník–Lovosice) | 13 | 6 | 7 | 0 | 0 |
| Vltava (Prague–Troja–Mělník) | 15 | 11 | 3 | 1 | 1 |
| **Total** | **46** | **32** | **13** | **1** | **1** |
| | **100.0 %** | **69.6 %** | **28.3 %** | **2.2 %** | **-** |

Legend: A – total number of ferries identified on the navigation chart as of 1950; B – number of ferries (out of the set in A) identified in the database for 1953–1955; C – number of ferries (out of the set in A) identified in the database, but not for 1953–1955; D – number of ferries (out of the set in A) completely missing in the database; E – number of ferries in the database, but not identified in the navigation charts periods, despite the positional tolerance of 50 m. This is mainly due to two factors: the very small number of ferries (33) currently in operation and the generally dynamic manifestations of changes in river flows in the landscape [9]. Approximately 56 % of detected ferries were recorded in only one time period, while some watercourses show an even higher proportion (Ohře river about 70 %). In contrast, some ferries were found to have existed for a long time, being identified on four different mappings from the mid-18th century (9 on the Elbe and another 9 on the Vltava). However, it should be noted that our data are limited to the mapping period, which means that any changes that occurred outside of these mappings may not have been captured.

An integral sub-theme of the research was the verification of information obtained both from topographic maps and from other auxiliary information sources. A comparison of the objects identified in the topographical maps and in the navigation charts of the Elbe and Vltava showed a correlation of almost 70 % of objects. With the exception of one object, all missing ferries were recorded at least on maps from an earlier period. As the concurrent analysis of the Water Books from the 1950s showed, the difference of 3–5 years between the topographic map and the navigation chart corresponds to the period of mass closure of many ferries. This is also supported by the fact that a number of missing sites were recorded during the 3rd Austrian mapping, reambulated in the 1930s and 1940s. In our research, these maps were used as an auxiliary source. In this context, it should be emphasized that the 1950s embodied a time of rapid social and economic change, as it followed the communist coup of 1948. The mentioned social processes included, among others, the motorization of the country and the improvement of the accessibility of settlements. The latter trend consisted of several conceptual steps, one of which was the construction of larger permanent bridge structures across rivers that replaced ferries [18, 19].

# CONCLUSIONS

A total of 542 ferries were found in Czechia from 1763 to 2022, of which 514 were on old topographic maps and another 28 were based on auxiliary sources. Therefore, we can say that old Austrian and Czechoslovak military topographic maps embody a valuable source of information in terms of identifying historical ferries. However, certain limitations should also be noted:

- The maps of the 1st Austrian military mapping show considerable positional inaccuracy, especially in terms of the cartographic depiction used and the quality of the map copies, which are about 250 years old;
- The content was processed by different cartographers, which means that there may be differences in recorded details across map sheets;
- Each map captures conditions at a specific time, suggesting that during the long periods of time between maps, some ferries may have come and gone without being recorded.

Despite these shortcomings, our database still represents the most extensive set of identified ferry sites in Czechia. As such, the dataset can provide valuable support to researchers in the field of historical geography, especially those focusing on the study of historic transport links and investigating the functional connections between settlements, large industrial facilities, and/or recreational activities.

The actual continuity of a specific object can only be determined on the basis of a comprehensive study of archival sources on the operation of the ferry, licenses and concessions, revisions, procedures for the construction of bridges in the vicinity, flood damage related to both the ferry and bridges, age-related deterioration, and other aspects. The same assumption also applies to the study of the driving forces that led to the creation or, conversely, the closure of ferries.

Importantly, the database opens the way to future geographical research of ferries, especially their spatial distribution along rivers and their relationship to various physical-geographical factors including, among others, orography, watercourse size, watercourse dynamics in floodplains, and soil cover composition. Within socio-economic geography, the functions of ferries can be analysed in terms of settlement growth and regional economy (such as industry and trade). Another viable topic is to explore ways of using recognized sites as points of interest to promote tourism in rural regions.

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# Atmospheric deposition as a possible source of surface water pollution

(Preliminary results of the project, part 1 – heavy metals)

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## SUMMARY

Concentrations of selected heavy metals in collected atmospheric precipitation and surface water were monitored at pilot sites in the Jizera Mountains, Moravian-Silesian Beskydy Mountains, and Bohemian-Moravian Uplands (Czechia) over the course of one year to determine the significance of the impact of precipitation on surface water quality in an otherwise relatively low anthropogenically influenced environment. The measurements show that, for some metals, atmospheric deposition in heavily loaded areas can cause significant inputs to surface water. The resulting balance of substance load is strongly influenced by the environment and its load in the past.


## INTRODUCTION

The Water Framework Directive (2000/60/EC) [1] requires EU member states to assess the state of groundwater and surface water in regular six-year cycles. In cases of failure to achieve good chemical and/or ecological status, it is necessary to determine the fundamental influences causing this situation and propose measures for its improvement. The assessment of the state of surface water bodies, which has been carried out in the Czech Republic since 2009 in accordance with Czech legislation in three-year cycles, repeatedly shows a high proportion of water bodies not achieving good chemical status in the case of certain priority substances according to Government Regulation No. 401/2015 Coll., and good ecological status in the case of some specific hazardous substances [2, 3]. Failure to achieve good status for some groups of substances is also recorded in water bodies where most of the potential anthropogenic influences can be excluded, and for which the possible main influence is the transfer of pollution to the aquatic environment from the air through atmospheric deposition. These groups mainly include heavy metals and polycyclic aromatic hydrocarbons (PAHs).

The TA CR project SS01010231 "*Dopady atmosférické depozice na vodní prostředí se zohledněním klimatických podmínek* (*Impacts of atmospheric deposition on the aquatic environment with consideration of climatic conditions*)" deals with this topic. The project builds on the methodology [4] which, among other things, based on available data, proposes procedures for assessing the danger for surface water bodies from the point of view of atmospheric deposition. The main problem with this part of the methodology was the unavailability of current and comprehensive data, as well as unverified procedures for their use. The aim of the project is to at least partially supplement these missing data and procedures. Part of the project solution is the quantification of pollution in various environmental components using field monitoring in selected pilot forest catchments. The aim of this activity is to verify the extent to which individual substances can affect the situation in the real environment, and to identify other factors increasing the risk of contamination entering the aquatic environment.

Due to the breadth of the topic and the number of results, it was not possible to process all the findings in one contribution. This article presents the results of the representation of selected heavy metals in the matrices of surface water and precipitation water, which were collected as throughfall and bulk deposition. Additional separate articles will deal with PAHs, a more detailed assessment of the relationships between the load of individual environmental components, and the use of biological materials as an indicator of anthropogenic influences.

## HEAVY METALS IN THE ENVIRONMENT

Due to their toxic effects, heavy metals represent a significant source of surface water pollution [5–7]. There are three decisive properties for determining the environmental hazard of metals: resistance, bioaccumulation, and toxicity. Heavy metals that are both persistent and bioaccumulative are more dangerous because they can accumulate in organisms and be transported from one environment to another [8]. Metals that occur most often in surface water and pose a risk to the environment are in particular: mercury (Hg), lead (Pb), cadmium (Cd), nickel (Ni), and arsenic (As), [9, 10]. In addition to natural causes, anthropogenic activities are also responsible for their occurrence in the environment, especially the burning of fossil fuels, industrial activities (metallurgy, surface treatment of metals and enamelling), the use of paints and pigments, and agriculture [11, 12]. Through emissions, heavy metals enter the atmosphere and from the air they subsequently deposit into water and soil [13]. Metal compounds occur in the atmosphere in the form of particles that are sorbed onto aerosol particles. The amount of metals in the aerosol varies throughout the year [14]. Other factors that influence the amount of metals in the atmosphere are: meteorological conditions, site location, possibilities of long-distance transport, and amount of emissions [15]. Long-distance transport of particles can take place in the atmosphere due to air masses, therefore high levels of heavy metal pollution can be found even in places without a direct source of pollution [16, 17]. From the atmosphere, heavy metals are transported to the Earth's surface by deposition, which is driven


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by gravity and can occur through two mechanisms: dry and wet deposition. Dry deposition is slower and does not depend on precipitation, while wet deposition is faster and is affected by the amount of precipitation and the rate of capture of particles on the droplet surface [18].

## METHODS USED

As part of the project, substances that cause poor water quality and at the same time are expected to be significantly transmitted through the air were examined and evaluated. Thus, the heavy metals As, Cd, Hg, Ni, and Pb were selected. From the point of view of the categorization of substances harmful to the aquatic environment, it should be mentioned that As is a specific pollutant, the other metals addressed in the project are priority substances, and Cd and Hg are priority dangerous substances.

To compare the presence of selected elements in different components of the environment, sampling of the following matrices was carried out in the model catchments:

- bulk deposition (monthly*),
- throughfall deposition (monthly*),
- surface water (monthly),
- river sediment (twice during the year),
- humus – a biologically stable humification layer (H, Oh horizon), after removal of litter layer (Ol) and fermentation horizon (Of) in the overburden (1x – samples represent a longer period of time),
- moss (1x – samples represent a longer period).

Note*: To determine the pollutants of interest in atmospheric deposition, it was necessary to obtain a sufficient volume of samples. In cases of insufficient rainfall, samples were taken after two months of exposure.


Fig. 1. Location of pilot areas

In water matrices, the total concentration of As, Cd, Hg, Ni, and Pb was determined by mass spectrometry and AAS-Hg methods. Spot samples of surface water were evaluated in the first part of the project by the ETA-AAS method for metals and AMA 254 for Hg. This is also the reason for higher detection limits for some of the results (for surface water in the first six months of monitoring).

For the project, model forest micro-catchments were selected, which were suitable for the monitoring of all the above-mentioned matrices and where, apart from the influence of the actual atmospheric deposition, other anthropogenic sources of pollution were not present.

The following catchments were selected as pilot areas:

- The area east of the Ostrava and Třinec agglomerations, which due to the prevailing air flow is heavily loaded with PAHs and heavy metals from the local power stations and industry, but at the same time it is a mountainous and forested area with no direct discharges into the watercourse. The model upper part of the Suchý stream basin in the eastern part of the cadastral territory of Bystřice has an area of 0.462 $km^2$ up to the sampling point. Suchý

Fig. 2. Precipitation sampling in Bystřice pilot area

stream is part of the catchment area of the HOD_750 – Hluchová water body from the source to the mouth of Olše, which in the third planning cycle does not reach good status due to the presence of PAHs. No other violations of Environmental Quality Standard (EQS) were detected. In the resulting tables, the catchment area is labelled Bystřice (BY), based on the nearest municipality.

— The area of the Bohemian-Moravian Highlands, which is considered to be an area with clean air, mainly influenced only by local heaters. In addition, areas with significant logging are currently expanding in this site after the bark beetle outbreak. It is therefore possible to monitor how deforestation and logging contribute to the leaching of hazardous substances. In contrast, it was necessary to avoid places with current and past mining of mineral resources. The model basin of the Lesní stream, a tributary of the Anenský stream on the north-eastern edge of the cadastral area of the Košetice municipality and the nearby meteorological station of the same name, has an area of 0.292 $km^2$ up to the sampling point. The stream is part of the catchment area of the DVL_0440 Martinický stream water body, which achieved good chemical status in the second and third cycles and EQS for selected substances were not exceeded. In the resulting tables, the catchment area is labelled Košetice (KO), based on the nearest municipality.

The area of the Jizera Mountains, which in the past was particularly affected by emissions of Cd and other metals from the nearby glass industry, and possibly from coal-fired power stations on the Polish side of the Jizera Mountains (in recent years, however, the air quality has improved). The model catchment of the Hřebový (sometimes also Hřebenový) stream, which is a left-hand tributary of the Souš reservoir in the municipality of Desná and Kořenov, has an area of 1,029 $km^2$ up to the sampling point. The stream is located in the catchment of the HSL_1896_J – Souš reservoir water body on the Černá Desná stream, which in the second planning cycle did not reach good chemical status due to exceeding EQS for Cd, and was not classified in the third cycle. In the resulting tables, the catchment area is labelled Desná (DE), based on the nearest municipality.

In these sites, rain gauges were placed near the watercourse, and a mixed sample of precipitation (collected over the entire period of one or two months) was always taken at the end of the given period. For the throughfall exposure, conifers (spruce in all three locations) were chosen because precipitation was also collected in winter. In the snow-free period, the upper part of the rain gauges was equipped with a protective net, so that the coarse solid particles and insects did not get into the collected water phase. The volume of collected precipitation was measured. Each collection campaign was photographically documented. Together with the precipitation collection, point sampling of surface water from the watercourse was carried out near the rain gauge station. The installation of rain gauges for the first sampling campaign took place on 6 October 2020 (BY), 7 October 2020 (KO), and 8 October 2020 (DE).

Data on the amount of precipitation obtained from the Czech Hydrometeorological Institute (CHMI) and confirmed by the actual measurements in the sites were attached to the individual campaigns. The flow rate in the watercourse at the time

Fig. 3. Hřebový stream in Desná

Fig. 4. Bulk precipitation sampling at Košetice pilot site (left: 6 November 2020, right: 7 January 2021)

*Tab. 1. Monthly precipitation amounts and flow rates at the time of measurement at individual sites*

| **Campaign** | **Date** | | **Precipitation [mm]** | | | **Flow rate [$m^3.s^{-1}$]** | | |
|---|---|---|---|---|---|---|---|---|
| | DE, BY | KO | BY | DE | KO | BY | DE | KO |
| 1 | 5. 11. 2020 | 6. 11. 2020 | 190.8 | 176.6 | 55.9 | 0.19 | 0.021 | 0.0008 |
| 2 | 7. 12. 2020 | 8. 12. 2020 | 22 | 35.1 | 9.2 | 0.003 | 0.033 | 0.0005 |
| 3 | 6. 1. 2021 | 7. 1. 2021 | 51 | 58.7 | 27.1 | 0.007 | 0.009 | 0.0004 |
| 4 | 5. 2. 2021 | 6. 2. 2021 | 122.2 | 124.3 | 65.1 | 0.018 | 0.118 | 0.0024 |
| 5 | 5. 3. 2021 | 8. 3. 2021 | 90.1 | 24.8 | 10 | 0.017 | 0.201 | 0.0014 |
| 6 | 6. 4. 2021 | 7. 4. 2021 | 89.6 | 73.9 | 21.2 | 0.012 | 0.026 | 0.0008 |
| 7 | 6. 5. 2021 | 7. 5. 2021 | 151.8 | 89.1 | 42.2 | 0.008 | 0.096 | 0.0008 |
| 8 | 7. 6. 2021 | 8. 6. 2021 | 179.2 | 88 | 86.8 | 0.005 | 0.182 | 0.0008 |
| 9 | 7. 7. 2021 | 8. 7. 2021 | 75.5 | 100.6 | 69.1 | 0.001 | 0.014 | 0.0015 |
| 10 | 6. 8. 2021 | 9. 8. 2021 | 192.1 | 164.2 | 126.9 | 0.001 | 0.016 | 0.001 |
| 11 | 6. 9. 2021 | 7. 9. 2021 | 224.8 | 144.6 | 19.9 | 0.017 | 0.011 | 0.0004 |
| 12 | 6. 10. 2021 | 7. 10. 2021 | 83.2 | 74.4 | 31.9 | 0.025 | 0.066 | 0.0004 |
| Total precipitation [mm] | - | - | 1,472.3 | 1,154.3 | 565.3 | - | - | - |
| **Average flow rate [$m^3.s^{-1}$]** | - | - | - | - | - | 0.025 | 0.066 | 0.0009 |

of sampling was estimated, by analogy with the flow rates at the nearest CHMI gauging stations. The ratio of the flow rate at the observed point of the experimental site and at the nearest gauging station was equal to the ratio of the area of the point catchments. The exception was the site in Košetice, where data was taken from regular measurements carried out by CHMI.

Based on the amount of precipitation and the detected concentrations of monitored pollution parameters in precipitation, an estimate of the total deposition for the given experimental basin was calculated according to the following formula:

$$RS = \sum Sx*Cx$$

where RS is annual deposition in the given catchment
Sx amount of precipitation in the given month per area of the catchment
Cx concentration of the pollutant in the throughfall sample of the given month

An estimate of the annual substance load of watercourses for a given pollutant was calculated on the basis of the calculated flow rate and the detected concentrations according to the following formula:

$$LOD = \sum Qx*Cx*d$$

where LOD is substance load
Qx instantaneous flow rate at the time of withdrawal
Cx concentration of the substance in the point sample
d length of the period to which the value refers, in this case one month

Values below the limit of determination were not included in the average; for the purpose of calculating the substance load, instead of concentrations below the limit of determination, the average of actually measured values was used if this was lower than the limit of determination, and the limit of determination if the average of the other values was higher. The usual procedure of using half the limit of determination was not used because comparison of the results of both methods of determination shows a large relative error of this procedure.

## RESULTS

Due to the different properties of the monitored substances, the results for each metal are presented separately. For informational purposes, the limit of good surface water status based on Directive 39/2013/EU [19] in the case of priority substances Ni, Cd, Pb, and Hg and from the methodology for evaluating the ecological status of surface waters [20] in the case of As is given for comparison. The EQS value means, as already mentioned, the Environmental Quality Standard, AA EQS value the annual average and the MAC EQS value the maximum acceptable concentration. The number of surface water bodies for which the limit for good status was exceeded during the evaluation for the second and third basin plans is also given. The total number of surface water bodies is 1 121 and 1 118 in the second and third planning cycles, respectively. The number of non-compliant water bodies indicates the importance of the substance from the point of view of the assessment of the surface water status. Significant differences between the evaluation in the second and third cycles for Ni and Pb are caused, among other things, by changes in evaluation methodologies, i.e. the use of determining the bioavailability of metals in the evaluation of the chemical status for the third planning cycle. Methodologies and results of status evaluation are discussed in more detail in [3]. In *Tab. 2–6*, values that are higher than the values of EQS for good surface water status are marked in red. Simultaneously, it must be emphasized that the EQS in the case of Ni, Cd, and Hg are set for the dissolved form of metals, while their total concentration was monitored as part of the project, the marking of values above EQS is therefore only indicative. The average annual value is compared with the value of AA EQS, measurements in individual months with the value of MAC EQS.

*Tab. 2. Lead concentrations in surface and precipitation water*

| Pb [µg.l$^{-1}$] | Bystřice | | | Desná | | | Košetice | | |
|---|---|---|---|---|---|---|---|---|---|
| **Campaign** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** |
| 1 | 1.11 | 0.584 | 1.503 | < 1.0 | 0.153 | 0.991 | < 1.0 | 0.775 | 0.307 |
| 2 | < 1.0 | 1.712 | 2.094 | < 1.0 | 0.237 | 1.388 | < 1.0 | - | - |
| 3 | < 1.0 | 0.828 | 2.627 | < 1.0 | 0.398 | 1.702 | 4.85 | 0.315 | 0.381 |
| 4 | < 1.0 | 1.832 | 1.893 | < 1.0 | 0.506 | 0.913 | 2.74 | 0.688 | 0.695 |
| 5 | < 1.0 | 2.33 | 4.35 | < 1.0 | 0.376 | 1.22 | < 1 | - | - |
| 6 | < 1.0 | 1.839 | 4.711 | < 1.0 | 0.525 | 2.846 | < 1 | 0.584 | 0.640 |
| 7 | < 1.0 | 0.620 | 2.302 | 1.63 | 0.292 | 1.764 | 1.87 | 0.591 | 1.141 |
| 8 | 1.934 | 0.555 | 2.020 | 0.664 | 0.252 | 2.819 | 0.501 | 0.374 | 0.865 |
| 9 | 0.114 | 0.745 | 2.959 | 1.098 | 0.285 | 1.899 | 0.509 | 0.136 | 0.319 |
| 10 | 1.85 | 0.692 | 6.11 | 2.41 | 0.194 | 1.39 | 0.528 | 0.154 | 0.632 |
| 11 | 0.512 | 0.495 | 0.841 | 1.03 | 0.152 | 1.59 | 1.38 | 0.725 | 0.272 |
| 12 | 0.013 | 0.065 | 0.076 | 1.434 | 0.194 | 0.868 | 0.059 | 0.083 | 0.136 |
| **Average** | 0.922 | 1.025 | 2.624 | 1.378 | 0.297 | 1.616 | 1.554 | 0.444 | 0.534 |

*Tab. 3. Nickel concentrations in surface and precipitation water*

| Ni [µg.l$^{-1}$] | Bystřice | | | Desná | | | Košetice | | |
|---|---|---|---|---|---|---|---|---|---|
| **Campaign** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** |
| 1 | < 2.0 | 0.562 | 2.808 | < 2.0 | 0.032 | 0.474 | 5.59 | 0.933 | 0.972 |
| 2 | < 2.0 | 0.217 | 1.334 | < 2.0 | 0.117 | 1.187 | 2.7 | - | - |
| 3 | < 2.0 | 0.0789 | 0.0861 | < 2.0 | 0.0861 | 1.2917 | 12.2 | 0.1461 | 0.9165 |
| 4 | < 2.0 | 0.180 | 0.537 | < 2.0 | 0.223 | 0.286 | 7.41 | 0.376 | 0.668 |
| 5 | < 2.0 | 0.249 | 1.625 | < 2.0 | 0.132 | 0.781 | 8.09 | - | - |
| 6 | < 2.0 | 0.262 | 1.105 | < 2.0 | 0.467 | 1.682 | 5.19 | 0.911 | 0.723 |
| 7 | < 2.0 | 0.269 | 0.560 | < 2.0 | 0.141 | 0.610 | 4.1 | 0.306 | 1.243 |
| 8 | 1.04 | 0.184 | 0.560 | 0.342 | 0.493 | 2.814 | 6.77 | 0.197 | 0.905 |
| 9 | 0.536 | 0.344 | 1.053 | 0.333 | 0.180 | 1.704 | 7.63 | 0.353 | 0.852 |
| 10 | 0.822 | 0.294 | 0.825 | 0.570 | 0.169 | 0.999 | 6.653 | 0.215 | 0.993 |
| 11 | 0.238 | 0.067 | 0.371 | 0.346 | 0.055 | 1.142 | 8.624 | 1.469 | 1.455 |
| 12 | 0.207 | 0.086 | 0.201 | 0.271 | 0.157 | 1.522 | 4.156 | 0.347 | 1.696 |
| **Average** | 0.569 | 0.233 | 0.922 | 0.372 | 0.188 | 1.208 | 6.593 | 0.526 | 1.005 |

*Tab. 4. Arsenic concentrations in surface and precipitation water*

| As [μg.l⁻¹] | Bystřice | | | Desná | | | Košetice | | |
|---|---|---|---|---|---|---|---|---|---|
| **Campaign** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** |
| 1 | < 1.0 | 0.107 | 0.218 | < 1.0 | 0.085 | 0.371 | < 1.0 | 0.122 | 0.205 |
| 2 | < 1.0 | 0.322 | 0.705 | < 1.0 | 0.082 | 0.715 | 1.1 | - | - |
| 3 | < 1.0 | 0.119 | 0.487 | < 1.0 | 0.092 | 1.958 | 1.29 | 0.104 | 0.098 |
| 4 | < 1.0 | 0.319 | 0.455 | 1.03 | 0.191 | 0.313 | < 1.0 | 0.124 | 0.165 |
| 5 | < 1.0 | 0.449 | 0.888 | 1.03 | 0.210 | 0.352 | < 1.0 | - | - |
| 6 | < 1.0 | 0.457 | 1.077 | < 1.0 | 0.228 | 0.758 | < 1.0 | 1.033 | 0.385 |
| 7 | < 1.0 | 0.173 | 0.422 | 1.02 | 0.078 | 0.425 | < 1.0 | 0.185 | 0.410 |
| 8 | 0.265 | 0.166 | 0.318 | 0.701 | 0.108 | 0.863 | 0.425 | 0.111 | 0.210 |
| 9 | 0.212 | 0.121 | 0.605 | 1.075 | 0.089 | 0.931 | 0.491 | 0.081 | 0.150 |
| 10 | 0.301 | 0.109 | 0.308 | 1.597 | 0.058 | 0.376 | 0.476 | 0.050 | 0.129 |
| 11 | 0.194 | 0.046 | 0.141 | 0.821 | 0.034 | 0.551 | 0.585 | 0.102 | 0.224 |
| 12 | 0.393 | 0.113 | 0.136 | 1.089 | 0.067 | 0.530 | 0.377 | 0.089 | 0.328 |
| Průměr | 0.273 | 0.208 | 0.480 | 1.045 | 0.110 | 0.678 | 0.607 | 0.262 | 0.232 |

*Tab. 5. Cadmium concentrations in surface and precipitation water (the colour marking of values above EQS is based on the limit for hardness class 1, i.e. soft to very soft water)*

| Cd [μg.l⁻¹] | Bystřice | | | Desná | | | Košetice | | |
|---|---|---|---|---|---|---|---|---|---|
| **Campaign** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** |
| 1 | < 0.1 | 0.035 | 0.0467 | 0.23 | 0.033 | 0.072 | < 0.1 | 0.045 | 0.035 |
| 2 | < 0.1 | 0.088 | 0.208 | 0.23 | 0.027 | 0.344 | < 0.1 | - | - |
| 3 | < 0.1 | 0.021 | 0.268 | < 0.1 | 0.025 | 0.477 | < 0.1 | 0.019 | 0.025 |
| 4 | < 0.1 | 0.045 | 0.135 | 0.21 | 0.041 | 0.107 | < 0.1 | 0.049 | 0.047 |
| 5 | < 0.1 | 0.121 | 0.504 | 0.19 | 0.033 | 0.170 | - | - | - |
| 6 | < 0.1 | 0.235 | 0.712 | 0.2 | 0.033 | 0.204 | < 0.1 | 0.081 | 0.036 |
| 7 | < 0.1 | 0.073 | 0.200 | 0.16 | 0.020 | 0.251 | < 0.1 | 0.075 | 0.113 |
| 8 | 0.108 | 0.039 | 0.113 | 0.103 | 0.026 | 0.300 | 0.037 | 0.026 | 0.046 |
| 9 | 0.034 | 0.050 | 0.194 | 0.107 | 0.021 | 0.202 | 0.041 | 0.072 | 0.040 |
| 10 | 0.091 | 0.105 | 0.134 | 0.272 | 0.041 | 0.110 | 0.036 | 0.095 | 0.059 |
| 11 | 0.037 | 0.048 | 0.023 | 0.122 | 0.010 | 0.129 | 0.038 | 0.039 | 0.014 |
| 12 | 0.056 | 0.0679 | 0.012 | 0.256 | 0.018 | 0.129 | 0.020 | 0.0164 | 0.027 |
| **Average** | 0.065 | 0.077 | 0.213 | 0.189 | 0.027 | 0.208 | 0.034 | 0.051 | 0.042 |

## Lead

The main source of Pb in water is primarily industry, and previously also transport, while a significant means of its penetration into the aquatic environment is transmission through the air. After the ban on the use of leaded fuels in 2001, Pb also enters the water through leaching from contaminated soil.

Limits of good status for surface waters: AA EQS = 1.2 μg.l$^{-1}$, MAC EQS = 14 μg.l$^{-1}$. Number of surface water bodies not meeting EQS in the Czech Republic in the second/third planning cycle: 43/4.

## Nickel

Ni occurs naturally in the Earth's crust and is also present in soil. It can be emitted by volcanic activity. In industry, it is often used in the manufacture of batteries, in metallurgy and in the manufacture of electronics. Ni is mainly found in the air as a result of the burning of fossil fuels. It gets into the water mainly by leaching from rocks and sediments.

Limits of good status for surface waters: AA EQS = 4 μg.l$^{-1}$, MAC EQS = 34 μg.l$^{-1}$. Number of surface water bodies not meeting EQS in the Czech Republic in the second/third planning cycle: 175/5.

## Arsenic

As occurs naturally in the earth's crust, it can also be present in ore deposits of coal. It can get into water from mine waters, and into the air by burning some types of coal.

Limit of good status for surface waters: AA EQS = 11 μg.l$^{-1}$.Number of surface water bodies not meeting EQS in the Czech Republic in the second/third planning cycle: 8/13.

## Cadmium

Cd is a relatively rare element in nature. It can enter the atmosphere through volcanic activity, during fires, or with dust particles during wind erosion and the burning of fossil fuels. In industry, it is used to a limited extent in the production of batteries, ceramics, electronics, and textile products. It enters surface waters mainly as part of industrial discharges and waters from the mining of non-ferrous metals or by transfer from the air.

Limits of good status for surface water depending on its hardness classes: AA EQS = ≤ 0.08 (class 1), 0.08 (class 2), 0.09 (class 3), 0.15 (class 4), 0.25 (class 5), MAC EQS = ≤ 0.45 (class 1), 0.45 (class 2), 0.6 (class 3), 0.9 (class 4), and 1.5 (class 5) μg.l$^{-1}$.

Number of surface water bodies not meeting EQS in the Czech Republic in the second/third planning cycle: 56/26.

*Tab. 6. Mercury concentrations in surface and precipitation water*

| Hg [μg/l] | Bystřice | | | Desná | | | Košetice | | |
|---|---|---|---|---|---|---|---|---|---|
| **Campaign** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** | **flow** | **bulk** | **throughfall** |
| 1 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | 0.175 | 0.036 |
| 2 | < 0.05 | 0.153 | 0.23 | < 0.05 | 0.29 | 0.305 | < 0.05 | - | - |
| 3 | < 0.05 | < 0.006 | 0.04 | < 0.05 | < 0.006 | 0.07 | < 0.05 | < 0.006 | < 0.006 |
| 4 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 |
| 5 | < 0.05 | 280 | 27.5 | < 0.05 | 15 | 13.8 | < 0.05 | - | - |
| 6 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | 0.35 | < 0.006 |
| 7 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 | < 0.05 | < 0.006 | < 0.006 |
| 8 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 |
| 9 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 |
| 10 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 |
| 11 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 | < 0.006 |
| 12 | < 0.006 | < 0.006 | < 0.006 | 0.067 | 0.087 | < 0.006 | < 0.006 | < 0.006 | < 0.006 |

*Tab. 7. Indicative comparison of concentrations of selected metals in other monitored matrices*

| [mg.kg$^{-1}$] | Stream sediment | | | Moss | | | Humus | | |
|---|---|---|---|---|---|---|---|---|---|
| | BY | DE | KO | BY | DE | KO | BY | DE | KO |
| As | 6.07 | 17.00 | 10.82 | 0.19 | 0.15 | 0.14 | 8.35 | 10.53 | 5.86 |
| Cd | 0.66 | 0.30 | 0.59 | 0.74 | 0.28 | 0.13 | 1.23 | 0.80 | 0.37 |
| Hg | < 0.2 | < 0.2 | < 0.2 | 0.05 | 0.03 | 0.03 | 0.39 | 0.37 | 0.37 |
| Ni | 16.05 | 8.21 | 62.33 | 0.85 | 0.83 | 0.98 | 8.72 | 7.65 | 7.41 |
| Pb | 30.25 | 42.50 | 29.77 | 8.39 | 2.56 | 1.48 | 127.00 | 74.87 | 45.07 |

*Tab. 8. Calculation of atmospheric deposition and substance load in pilot areas*

| **Substance** | **As** | | | **Pb** | | | **Cd** | | | **Ni** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | BY | DE | KO | BY | DE | KO | BY | DE | KO | BY | DE | KO |
| Atmospheric deposition [g.year$^{-1}$] | 269 | 718 | 34 | 1,763 | 1,849 | 97 | 116 | 207 | 8 | 649 | 1,334 | 161 |
| Atmospheric deposition per area unit [g.km$^{-2}$. year$^{-1}$] | 583 | 697 | 115 | 3,817 | 1,797 | 331 | 250 | 201 | 27 | 1,404 | 1,296 | 553 |
| CHMI 2020 total deposition [Ni only bulk] | - | - | - | 600–1,300 | 600–1,000 | 100–400 | 55–70 | 200–400 | 15–35 | 1,000–1,500 | 3,000–5,000 | 750–1,000 |
| Substance load [g/year] | 219 | 1,982 | 17 | 752 | 2,191 | 40 | 50 | 364 | 1 | 417 | 739 | 195 |
| Substance load per area unit [g.km$^{-2}$year$^{-1}$] | 474 | 1,926 | 57 | 1,628 | 2,129 | 138 | 108 | 354 | 3 | 903 | 718 | 667 |
| Ratio of load and deposition [%] | 81 | 276 | 49 | 43 | 118 | 42 | 43 | 176 | 13 | 64 | 55 | 121 |

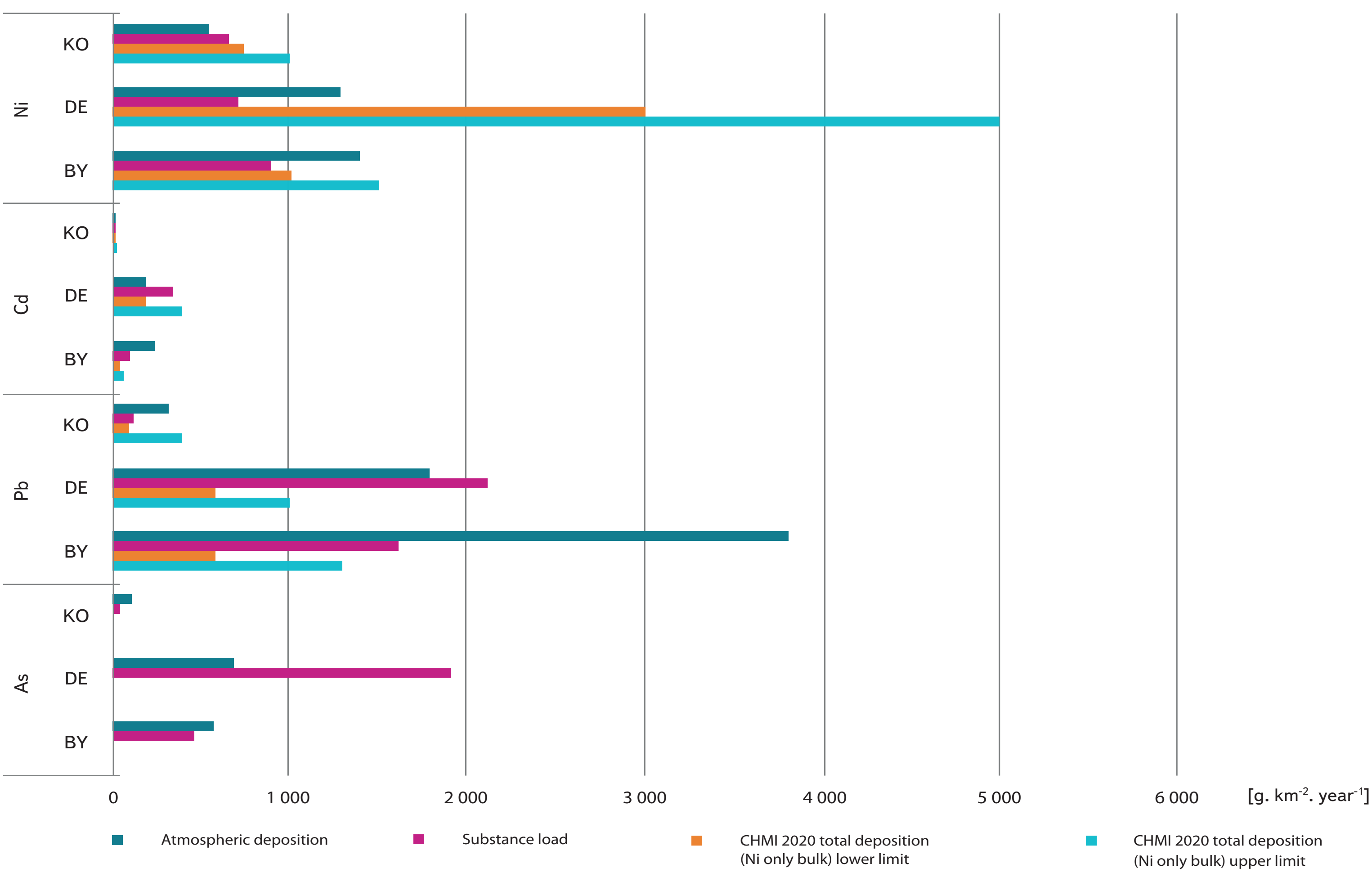


Fig. 5. Calculation of atmospheric deposition and substance load per area unit

## Mercury

Hg occurs naturally in rocks and soils. From a global perspective, the increased Hg content of the recent zone reflects recent and past tectonic and volcanic activity.

An increased concentration of Hg in natural waters is usually the result of anthropogenic pollution. Hg compounds can be contained in waste water from some types of industrial production, it can get into the air by burning fossil fuels and by wind drift during surface mining.

Hg has a high accumulation potential, especially in sediments and in aquatic flora and fauna.

Limit of good status for surface water: MAC EQS = 0.07 $\mu g.l^{-1}$.

The number of surface water bodies not meeting EQS in the Czech Republic in the second/third planning cycle: 75/95.

*Tab. 7* shows a comparison of the values measured in the other monitored matrices. These are average values from two to three measurements in the case of stream sediment and from three sites in each catchment in the case of moss and humus. The methodology and more detailed results will be published in the following article; however, even the summary data indicate an increased deposition level for Pb and Cd in the industrial sites of Desná and Bystřice, and, in contrast, a relatively uniform level of deposition for Ni, As, and Hg.

*Tab. 8* and *Fig. 5* provide an overview of the calculated atmospheric deposition and substance load, both absolutely and relatively per area unit in the experimental sites, and compare them with the values reported by CHMI [21].

The comparison of the calculated relative values shows that the highest values of both deposition and substance load are achieved by concentrations of Pb or Ni, while the lowest values were confirmed for Cd.

The order of concentrations of individual substances in relative atmospheric deposition is Pb > Ni > As > Cd, with the exception of Košetice, where Ni is in first place (Ni > Pb > As > Cd). The order of magnitude of the substance load varies in each site; the lowest values remain common in the case of Cd.
Košetice Ni >> Pb > As >> Cd
Desná Pb > As > Ni > Cd
Bystřice Pb > Ni > As > Cd

# DISCUSSION

The measurements carried out confirm that, in the case of some metals, precipitation pollution is comparable to surface water pollution. In the case of metals, no significant seasonality was noted for the pollution of precipitation and surface water. It should be noted that for surface water the result is affected by the high limit of determination in the first half of annual monitoring. The calculated atmospheric deposition is comparable to the calculated substance load in the given basin, although both calculations are burdened with a considerable degree of uncertainty. As expected, higher substance load than deposition was recorded at the Desná site, where a higher load of selected metals in the past is assumed. Closer connections will be possible to evaluate with the involvement of evaluation of other monitored matrices in experimental sites.

Specific assessments for individual metals:

## Lead

Pb concentrations are decreasing in the long term [22], both in the air and in surface water. The calculated atmospheric deposition can be compared with the values determined within other projects, e.g. [7] reports deposition of 5.8 or 9.3 $kg.km^{-2}.year^{1}$ in two sites in Krkonoše mountains. By comparison with the value of the calculated deposition at the Desná site of 1 797 $kg.km^{-2}.year^{1}$, this indicates that there has been a significant reduction in Pb deposition in the past 17 years.

The Pb concentration in precipitation is comparable to its concentration in surface water, but it can be even higher in sites affected by industry (especially metallurgical processing of non-ferrous metals). The concentrations in throughfall precipitation alone can then reach EQS levels, which would pose a risk in the case of an impact on water surface or in the case where precipitation waters are discharged into surface waters without interaction with the environment, if it were a dissolved form of Pb in precipitation water.

The calculated deposition corresponds to the values reported by CHMI for 2020 in the Košetice site; in other sites it is higher, which may be due to local conditions (e.g. in the Bystřice site, a particularly exposed site was chosen; CHMI, on the other hand, works with a modelled network with a step of 1 km), or with a time shift (CHMI year 2020, measurement within the project 10/2020–9/2021).

## Nickel

Increased concentrations of Ni in precipitation were not detected in the monitored sites. In the pilot basin of Košetice, higher Ni concentrations were detected in surface water; significant input of Ni to the site from precipitation was not confirmed. It can therefore be assumed that surface water pollution in the Košetice site comes from a different source than the current atmospheric deposition, which is also consistent with the evaluation of other matrices.

The calculated deposition corresponds to the values given by CHMI in the Bystřice site; in the Desná and Košetice sites the values calculated from the data obtained as part of the project were lower.

## Arsenic

Precipitation values in all sites including those affected by coal mining and burning are higher, but well below the EQS value for surface water. The highest values in surface water were recorded at Desná, where a higher load can be assumed in the past.

## Cadmium

As expected, the lowest concentrations in both precipitation and surface water were measured in the lightly loaded Košetice basin, which served as a reference site for the other two. Higher concentrations in precipitation were measured in Bystřice and Desná, i.e. sites affected by industry and coal burning. These detected concentrations are higher than the EQS values for surface water, if we do not consider the limit values determined for the highest hardness class and the validity of the EQS values for the dissolved form of cadmium. While in the Bystřice site, the highest deposition was recorded, but lower substance load, in Desná, the substance load by the Hřebový stream was, on the contrary, higher. The cause is probably a higher load of cadmium in the given area in the past from nearby sources of air pollution (glass industry) with the accumulation of this pollution in the upper soil layers.

The calculated deposition corresponds to the values reported by CHMI, with the exception of the Bystřice site, where it is significantly higher.

## Mercury

Due to the frequent values below the detection limit, it was not possible to determine the atmospheric deposition and substance load. Hg occurred in the surface water of the model areas only once (Desná) in a concentration just below the EQS limit. In the precipitation, we could observe two episodes when Hg was measurable, even in several sites simultaneously. The campaign at the beginning of November 2020 ended with a question mark when there was an increased concentration of Hg in the Košetice site. In the other two areas, increased concentrations did not occur until the December campaign; however, we must consider that the campaigns in Košetice were always concluded one day later than in the other two sites. In the March campaign, on the other hand, increased Hg concentrations in Košetice occurred later and at lower values; however, due to the lack of precipitation, this is a sample taken after a two-month exposure. These increased concentrations of Hg are correlated with the passage of dust from the Sahara Desert through the territory of the Czech Republic, while it is confirmed in literature [23] that areas regularly exposed to these phenomena are also more loaded with Hg. The occurrence of Hg in surface water is sporadic. Nevertheless, due to its high bioaccumulation potential, it is significantly represented in biota, accompanied by the failure to achieve good chemical status of surface waters. However, this problem is not specific only to the Czech Republic; due to the physical-chemical properties of Hg and its behaviour in the environment, it is a worldwide issue.

# CONCLUSION

The project confirmed that air pollution can have a significant effect on surface water quality through atmospheric deposition. Environmental characteristics, including historical deposition, also play a significant role. This risk is particularly evident for Pb and Cd. In the case of As and Ni, on the other hand, atmospheric deposition does not appear to pose a threat to surface water quality in the selected sites. Hg is characterized by special properties which, in addition to requiring more complex laboratory processing, also shows much more significant fluctuations in values. In precipitation in particular, the amount of Hg can change significantly, apparently also in connection with distant external influences.

We will provide a more detailed description of the representation of metals in the monitored matrices within the framework of this project and the links between the pollution of individual components of the environment in one of the following articles. All outputs to date are available on the project website [24].

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# Food waste issues in relation to the mandatory reporting of its production for the needs of the Waste Framework Directive

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**Keywords:** food waste — food loss — production — reporting — circular economy

## SUMMARY

From this year, European Union member states are obliged to introduce preventive measures that will reduce the amount of food waste at all stages of the food chain. This article deals with this current topic, presents possible procedures for obtaining data on food waste production at various stages of the food chain, and shows the results of our own research and analysis about the usability of these data for reporting obligations and demonstrating future reductions.

## INTRODUCTION

Solving the issue of food waste (sometimes referred to as gastro-waste) is one of the main priorities not only for the European Union (EU), but for the entire world. The reason is wasting of food, which, according to a study by the United Nations (UN) Food and Agriculture Organization (FAO), represents approximately one third of global food production – it is either food lost or wasted [1]. The FAO study also states that industrialized countries waste significantly more food than developing countries, especially at the consumer level. For example, consumers in Europe and North America produce 95 to 115 kg of food waste per capita per year, while in sub-Saharan Africa and Southeast Asia only 6 to 11 kg per capita is generated. For this reason, the UN committed to achieving global sustainable development by 2030 (the 2030 Agenda). This global action plan established 17 Sustainable Development Goals (SDGs) and 169 specific sub-goals in three areas of sustainable development: economy, society, and environment. SDG target 12 focuses on ensuring sustainable patterns of production and consumption. Specific objective 12.3 covers both food loss and waste reduction. It calls for halving global food waste at the retail and consumer levels, as well as reducing food losses within production and supply chains, including post-harvest losses [2]. This action plan was later implemented by introducing the Monitoring Framework for the circular economy (European Commission, 2018), in which food waste is explicitly listed as one of the ten circular economy indicators [3, 4]. The UN action plan has also been incorporated into EU legislation. Specifically, it is Directive 2018/851/EC of the European Parliament and the Council of 30 May 2018, amending Directive 2008/98/EC on waste, which states that member states should take measures to support the prevention and reduction of food waste in line with the 2030 Agenda for Sustainable Development adopted by the UN General Assembly on 25 September 2015, and in particular with its aim to reduce global food waste per capita at the retail and consumer levels and reducing food waste in production and supply chains, including post-harvest losses by half by 2030. These measures should be aimed at preventing and reducing food waste in primary production, during processing and manufacturing, in retail and other distribution of food, in restaurants and food services, and in households. In order to contribute to the achievement of the UN Sustainable Development Goal, member states should strive to achieve the indicative EU-wide target of reducing food waste by 30 % by 2025 and by 50 % by 2030. With regard to the environmental, social, and economic benefit of preventing the creation of food waste, member states should take specific measures in this area, including illustrative educational campaigns that would clearly show how to prevent the creation of food waste, and would become an official part of the adopted programmes. Member states should also measure progress made in reducing food waste. A common methodology should be established to measure the rate of this progress and also to facilitate the exchange of best practices between EU member states, as well as between individual food business operators. Based on such a methodology, reports should be submitted every year on the results achieved in reducing food waste.

## METHODOLOGY AND DATA SOURCES

According to Directive 2008/98/EC of the European Parliament and the Council on waste (hereinafter referred to as the Waste Framework Directive), food waste falls under the definition of biological waste (biodegradable waste from gardens and parks; food and kitchen waste from households, offices, restaurants, wholesale, canteens, catering, and retail facilities; and comparable waste from food industry facilities). The same Directive states the definition of food waste as all food within the meaning of Article 2 of Regulation (EC) No. 178/2002 of the European Parliament and the Council that has become waste. Act No. 541/2020 Coll., on waste, adopted this definition of food waste, but the problem arises with the first and second stages of the monitored chain. The Waste Act, in letter d) paragraph 1 Section 2, states that it does not apply to excrement, straw, and other natural substances from agricultural production and forestry that do not exhibit any of the hazardous properties listed in the Annex to the directly applicable regulations of the EU on the hazardous properties of waste and they are used in agriculture and forestry in accordance with the Fertilizer Act or to produce energy through procedures and methods that do not harm the environment and do not endanger human health. These losses are not captured in the waste management system, and their amount or percentage is very difficult to determine.

The annual food waste reporting obligation introduced by the Waste Framework Directive applies from 2019, when the delegated decision was adopted, with the first reference year being 2020. The aim of reporting is to monitor and evaluate the implementation of measures to prevent food waste in member states using common methodology for measuring the level of food waste at different stages of the food chain. The common methodology is established by two decisions of the Commission.

The first is Commission Delegated Decision (EU) 2019/1597 of 3 May 2019 supplementing the Waste Framework Directive with regard to a common methodology and minimum quality requirements for the uniform measurement of food waste stages. The amount of food waste is measured separately for each of the five stages of the food chain. Specifically, the stages are:

- primary production,
- processing and manufacturing,
- retail and other distribution of food,
- restaurants and food services,
- households.

For each stage of the chain, Annex II assigned the types of food waste that are usually found within it; see *Tab. 1.*

Annex III of Commission Delegated Decision 2019/1597 recommends methods for measuring food waste produced by a certain sample of food business operators and households using one of the following methods or their combination or other equivalent methods, in terms of relevance, representativeness, and reliability.

The direct measurement method is recommended for all stages of the food chain. Direct measurement includes various methods such as direct counts and weight and/or volume assessment. It generally provides the most accurate data, but is associated with high demands on costs, time and expertise, as well as direct access to food waste streams (through personal observations or communication with farms, businesses, and retail markets). In households, direct measurement includes kitchen scales, measuring cups, or other conventional measuring tools. Its strengths include the ability to update progress over time and track food waste [5].

For the first to third stages of the food chain, the Commission Decision recommends using weight balance. It measures food loss and waste by comparing inputs with outputs and taking stock changes into account. The literature [6, 7] states that one of the most common approaches to account for food loss and waste is material flow analysis (MFA), which has been successfully applied at different levels from individual products [8] to industries [7], but also at a macro level when analysing entire national systems [6] and wider geographical areas, e.g. the EU.

The measurement of food waste in the stages of retail sale and other of distribution food, restaurants and food services, and households is recommended

*Tab. 1. Waste codes occurring at each stage of the food chain*

| Stage | Waste code | Waste name |
|---|---|---|
| Primary production | 02 01 02 | Animal tissue waste |
| | 02 01 03 | Plant tissue waste |
| Processing and manufacturing | 02 02 | Wastes from the preparation and processing of meat, fish, and other foods of animal origin |
| | 02 03 | Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation |
| | 02 04 | Wastes from sugar processing |
| | 02 05 | Wastes from the dairy products industry |
| | 02 06 | Wastes from the baking and confectionery industry |
| | 02 07 | Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) |
| Retail and other distribution of food | 20 01 08 | Biodegradable kitchen and canteen waste |
| | 20 01 25 | Edible oil and fat |
| | 20 03 01 | Mixed municipal waste |
| | 20 03 02 | Waste from markets |
| | 16 03 06 | Organic wastes other than those mentioned in 16 03 05 |
| Restaurants and food services | 20 01 08 | Biodegradable kitchen and canteen waste |
| | 20 01 25 | Edible oil and fat |
| | 20 03 01 | Mixed municipal waste |
| Households | 20 01 08 | Biodegradable kitchen and canteen waste |
| | 20 01 25 | Edible oil and fat |
| | 20 03 01 | Mixed municipal waste |

to be carried out using waste composition analysis – this is a methodology of physical separation, weighing, and categorization of food waste flows from other materials that are not considered food waste, such as packaging or other solid waste. Analysis of waste composition provides accurate data and offers information about food waste (e.g. packaged or non-packaged food, as well as fruit and vegetables), which can help analyse financial costs and nutritional content. However, this methodology is expensive, requires a large sample, and does not provide information on the reasons for food waste [9].

The methodology recommends solving the problem of an insufficient amount of data from the stages of primary production, processing and manufacturing by means of questionnaires and interviews, coefficients and production statistics, as well as by analysing the composition of waste. According to Møller et al. [10], a questionnaire is a formal, structured way of collecting quantitative and qualitative data from participants and could be used to obtain data on the amount of food waste and other information from producers (growers), processors, retailers, and consumers (e.g. on waste management, awareness of the problem). In general, questionnaires, surveys and interviews are considered to be of equal information value and can be divided into two categories: those used to collect existing data (to assess reliability) and those used to estimate new amounts of food waste [9]. Questionnaires, surveys, and interviews can be conducted by telephone, electronically (online), via e-mail, or in person. The advantages of these types of surveys are that they are cost-effective, can be standardized, are among the most popular methods, and can reach a large number of people. However, they rely on intermediaries, sometimes creating misunderstandings between participants because respondents tend to underestimate the amount of waste they generate. In addition, low response rates tend to be noted.

The second decision defines the reporting format and is called Commission Implementing Decision (EU) 2019/2000 of 28 November 2019 establishing a format for reporting data on food waste and for submitting a quality control report in accordance with the Waste Framework Directive. The guidelines for reporting food waste and food waste prevention under this Implementing Decision aim to promote harmonized reporting of food waste and food surplus data by providing guidance and explanations based on the provisions of the legislation and the methodological framework.

There are currently two methodological approaches to estimating food waste in EU countries. One approach is based on MFA and combines statistical information on the production and trade of food products with food waste coefficients. The second approach estimates food waste based on waste statistics (WS). Both approaches are illustrated in the literature [11] using case studies carried out in three EU countries (Italy, Germany, and Denmark) and a comparison of the obtained results. The added value of such a comparison is that it allows identification of potential anomalies because both approaches rely on different data sources. Food waste estimates obtained using the MFA approach are generally higher than those obtained using the WS approach. The differences are more significant for the initial/primary stages of the food chain, i.e. primary production and food processing and manufacturing. These discrepancies are very probably caused by under-reporting of waste recorded by the relevant statistics because food flows generated in these stages can be processed on site in such a way that they do not become waste at all (e.g. burning residues for energy production, anaerobic digestion) and therefore do not need to be reported. Other issues that affect food waste estimates based on WS, and which may explain the differences found, are the effect of water content on the weight of food waste and the fact that countries have their own waste codes. Other inconsistencies may stem from differences between national classification systems and the one adopted by Eurostat, as well as uncertainty regarding the statistical data used because these data are reported from multiple sources and are inherently of varying quality. The latter problem also affects the MFA model, which uses statistical data as well. However, the model presents a comprehensive picture of the food system, as it provides a breakdown of food waste estimates by stage of the food supply chain and by food group, allowing the identification of critical food groups and stages of the food chain. This is particularly important as it can support the design of effective measures to prevent food waste after combining its findings with environmental aspects to ensure that food groups with the greatest integrated impacts are prioritized. Although country-specific coefficients should be collected to improve the robustness of the MFA approach, the model developed has the potential to be used to assess food waste data more broadly [2].

## Quantifying food waste in EU countries using material flow analysis (MFA)

In the original MFA model, food waste was defined as "any food, and inedible parts of food, removed from the food supply chain" to be recovered or disposed of (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea) [12]. Instead, in the current model (version 1.0), the definition of food waste has been aligned with the EU definition of food waste (see section 2.2), which excludes crops left in the field or ploughed and the mortality of animals ready for slaughter in reporting food waste. However, these amounts are estimated by the updated model and are labelled as "food losses". The amount of food waste is calculated at different stages of the food chain and is given in dry weight. The model follows a territorial approach that does not account for food waste contained in net imports of raw materials and manufactured products.

# METHODOLOGY FOR DATA ACQUISITION

The aim of our research was to collect data on the production of food waste in all stages of the food chain. Due to the absence of necessary sources of data, especially from the primary producers of food waste (i.e. for the stages of primary production and processing and manufacturing), the method of direct contact and request to fill in the questionnaire was chosen (the questionnaire is shown in *Tab. 2*).

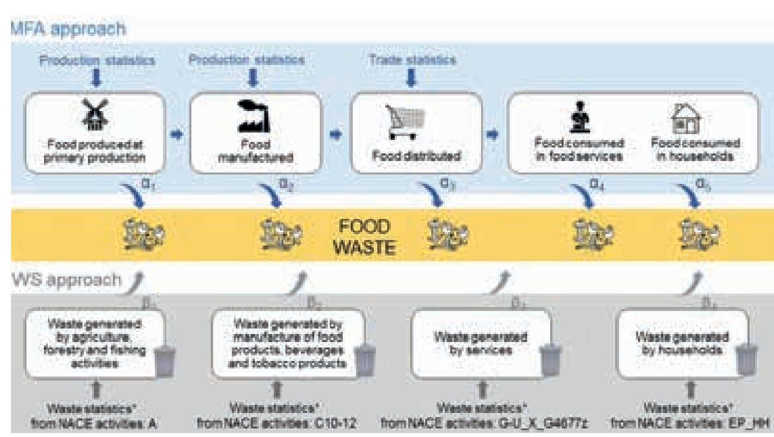


Fig. 1. Food waste model. Source: [13]

*Tab. 2. Questions in questionnaires for waste catalogue number 02 01*

| | |
|---|---|
| 1. | If you report waste under code 02 01, can you briefly specify what kind of waste it is? |
| | If you report waste under code 02 01, can you specify whether it is a mixture of different materials/waste or a homogeneous material/waste? (Tick one option.) |
| 2. | a mixture of different materials/waste |
| | homogeneous material/waste |
| 3. | If you report waste under code 02 01, does it include waste that can be considered as food loss (food loss in operation, when food is removed from further processing or sale in the given food chain, but is not necessarily degraded to waste, as it can be used by someone else as food for human consumption)? (If YES, go to question 4, otherwise go to question 9.) |
| | YES / NO |
| 4. | Can you briefly describe what products or waste are specifically involved in the case of the considered food losses? |
| 5. | Do you record food losses in your waste production? (If YES, go to question 6, otherwise go to question 9.) |
| | YES / NO |
| 6. | If you record food losses, state their total amount in relation to the total amount of waste produced by you. *(Express in %.)* |
| | If you record food losses, can you estimate which aspects contribute to the occurrence of food losses? *(Express as a % to a total of 100 %.)* |
| | production technology |
| | handling |
| 7. | packaging |
| | transport |
| | customer requirements |
| | other (specify): |
| | If you record food losses, can you assess whether the following facts have an effect on their production? *(Tick one or more options.)* |
| | seasonality |
| 8. | customer requirements for the quality of raw materials |
| | fashion trends |
| | other (describe): |
| | If you report waste under code 02 01, state the reasons for which you cannot use it materially (e.g. for the production of animal feed, your own compost, etc.) (Tick one or more options.) |
| | hygienic |
| | veterinary |
| 9. | legislative |
| | capacity |
| | no demand |
| | other (describe): |
| 10. | If you produce waste 02 01 99, please specify it briefly. |

*Tab. 3. Number of producers approached and return of responses for each waste catalogue number. Source: WRI TGM, p. r. i.*

| **Waste catalogue number** | **02 01 02** | **02 01 03** | **02 02 02** | **02 02 03** | **02 03 04** | **02 05 01** | **02 06 01** | **02 07 01** | **Retail chains** |
|---|---|---|---|---|---|---|---|---|---|
| Number of producers approached | 28 | 30 | 21 | 19 | 20 | 20 | 17 | 18 | 10 |
| Number of producers who responded | 2 | 4 | 4 | 3 | 7 | 3 | 2 | 2 | 1 |

### 02 01 Waste from agriculture, horticulture, fishing, forestry and hunting

A total of 183 producers were interviewed. Specific data for each waste category are shown in *Tab. 3*. The number of completed questionnaires, including answers obtained by telephone or e-mail communication, was a total of 28. This is a 15 % return. The most common justification for unwillingness to cooperate was non-obligation. Reluctance also resulted from the current energy and Covid crises connected with the financial, personnel, and the problem of overall survival of the producers.

## ANALYSIS OF WASTE COMPOSITION – MEASUREMENT

We chose direct measurement methods to obtain data on food waste production in the restaurant and food service and household stages. Due to the limited possibilities of entering premises, we took advantage of the opportunity to obtain data from other projects and analysed 4.5 tons of waste from kitchens and canteens (20 01 08) (restaurant and food services stage), about 1 ton of sorted biodegradable waste (20 02 01), and about 5.5 tons of mixed municipal waste (household stage).

The analysis of waste from kitchens and canteens (specifically restaurants and school canteens) was focused on composition in terms of edible and

Fig. 2. Samples of analyzed gastro-waste. Source: WRI TGM, p. r. i.

Fig. 3. Analyzed sorted biodegradable waste. Source: WRI TGM, p. r. i.

Fig. 4. Sorted components of mixed municipal waste – gastro-waste (left) and compostable waste (right). Source: WRI TGM, p. r. i.

(in our cultural conditions) inedible parts of food. As inedible parts of animal foods, we included eggshells, bones, claws, etc. and peels of citrus fruits, onions, melons, etc., and hard parts of stems, pome cores, drupe stones, etc. for plant foods. We also distinguished foods that were raw and cooked. The cooked state for vegetable waste means it is edible. We also included baked goods, pasta, and dumplings in cooked foods of plant origin. In the case of cooked inedible food of animal origin, these are mainly beef or poultry bones from broths or from baked or boiled portions of meat.

Another examined material was sorted biodegradable waste (20 02 01). These were collections from Prague city districts, in which sorting of the biological component of municipal waste was introduced as a pilot. During the project, we analysed approximately 1 ton of waste, which we sorted into the following components: garden waste with soil; fruits and vegetables; coffee grounds and tea bags; compostable packaging; baked goods and pasta; meat and bones; eggs/shells; dairy products; beverages excluding dairy; food packaging; beverage packaging; other plastic; textile; inert material (stone, construction waste).

As part of data collection for reporting the production of food waste from households, we examined mixed municipal waste, or the content of gastro-waste and garden waste from Prague housing estates. The recording of these two items was carried out separately in order to make it clear whether it is waste suitable for composting, registered as garden waste, or gastro-waste which is of organic origin but not suitable for composting. Compostable kitchen waste such as peels and normally unconsumed parts of fruits, vegetables, and flower root bundles together with soil were included in the garden waste component. Gastro-waste, or kitchen waste, was the remains of food from preparation and cooking or unconsumed food intended for direct consumption.

## SURVEY RESULTS

The results of the questionnaire survey can be summarized as follows:

— Out of 28 producers, only 3 answered that their waste is food loss. Those who stated that their waste was food loss also recorded it, with one accounting for 0.5 %, another 1 %, and the last 3 %. The reasons why waste is not materially used were legislative (36 %), veterinary (36 %), hygienic (27 %), capacity (18 %), and technological (9 %).
— All waste producers of category 02 01 (Waste from agriculture, horticulture, fishing, forestry, and hunting) agreed that it was not food waste. Specifically, it was the remains of straw, hay, and other biomass from agriculture and forestry.
— For waste producers of category 02 02 (Waste from the production and processing of meat, fish and other foodstuffs of animal origin) it was food loss. In one case, these were sudden situations regarding cargo spoilage after a cooling system failure, one-off incidents, and in another case, this catalogue number includes hams from production before the expiration date, badly sliced ham, defective labels, and customer returns.
— For waste producers of category 02 03 (Waste from the production and processing of fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco; waste from the canning industry, from the production of yeast and yeast extract, from the preparation and fermentation of molasses) inedible waste was declared as: chaff from grain cleaning; unwanted spices; sludge from peeling, cleaning and separation of oil seeds; waste scraps.
— For waste catalogue number 02 05 (Waste from the dairy industry), the waste is food loss in the case of discarded dairy products of poor quality. Waste is not further processed due to capacity and the presence of plastic packaging. The reason for the losses is milk processing technology. In another case, it was sludge from the treatment of wastewater from the production of dairy products.
— In the case of qualitatively unsatisfactory products from the entrances and exits of the production line, production intermediates, processed sugar, input raw material (fat, glucose) in the form of syrup, and for the mass in the final form without the initial packaging or in the initial packaging, the waste was reported under the catalogue number 02 06 (Waste from bakeries and confectionery production).
— For waste catalogue number 02 07 (Wastes from the production of alcoholic and non-alcoholic beverages excluding coffee, tea and cocoa), we were met with reluctance to cooperate due to concerns about disclosure of the recipe, but it was stated that the reported waste is a silica filter plate with no “food” residues.
— Only one of the retail chains that were approached responded to the questionnaire on waste catalogue number 02 03.

The results of gastro-waste analysis are shown in *Fig. 5*. Gastro-waste collected mainly from school canteens and restaurants contained the most cooked edible food of plant origin, up to 57 %. The other groups reached almost the same amount. Raw edible and raw inedible food waste of plant origin was contained in gastro-waste to the amount of 8 % and 10 %, respectively. Cooked edible and cooked inedible food waste of animal origin comprised 8 % and 13 %, respectively. The lowest was cooked inedible food waste of plant origin, at 0.5 %, and impurities in the form of cigarette butts, paper napkins, latex gloves, beverage packaging, etc. (0.3 %).

Sorted biodegradable municipal waste consisted, on average, of 83 % garden waste and soil, 14 % fruits and vegetables, and the remaining items represented up to 1 % of the total weight. The garden waste and soil component mainly consisted of chopped grass, leaves, flowers (flowers with decorations/wrapping from purchase – decorations and packaging were removed and included in undesirable impurities), soil, and turf. The component of vegetables and fruits, including their inedible parts, was represented not only by peels, but also whole pieces of potatoes, carrots, heads of lettuce, cabbage, peels of citrus fruits, melons, pineapples, etc. Waste was weighed without sales packaging.

The analyses showed that, for the introduction of a biowaste sorting and collection system, it is very important to raise awareness, educate, and prepare the population for such a waste management system. Practice tested the influence of the quality of preparation for the introduction of biowaste processing on the quality and success of circular economy solutions in a region. It was clear from the analyses carried out that, although information on suitable and unsuitable waste for composting is provided in a consistent manner, the quality/purity of the sorting was very different.

On average, the organic part of mixed municipal waste consisted of garden waste (11 %) and gastro-waste (10 %). These items were recorded separately to make it clear whether they are waste suitable for composting, registered as garden waste, or gastro-waste, which is of organic origin but not suitable for composting. Compostable kitchen waste, such as peels and normally unconsumed parts of fruits and vegetables, garden waste such as leaves, grass, soil and branches, were recorded in the garden waste component. Gastro-waste, or

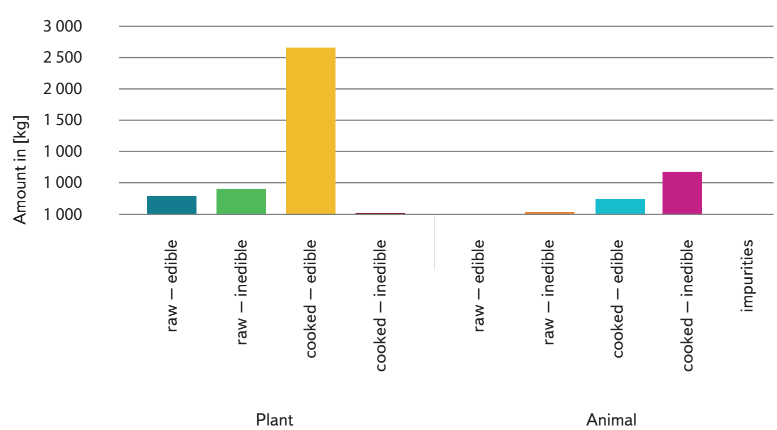


Fig. 5. Composition of gastro-waste (20 01 08). Source: WRI TGM, p. r. i.

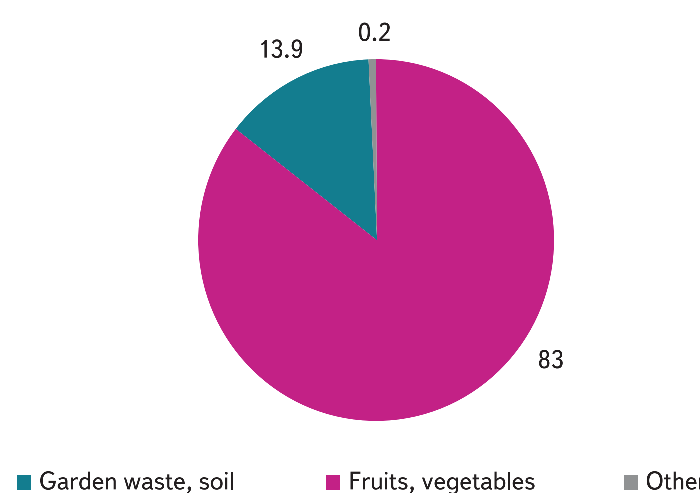


Fig. 6. Percentage composition of sorted biodegradable waste (20 02 01). Source: WRI TGM, p. r. i.

kitchen waste, was the remains of food that were either already cooked or were in a raw state. The samples often showed a large amount of baked goods, with less meat and dairy products. In the central parts of Prague in particular, gastro-waste included items related to fast food or restaurants in terms of composition and quantity. This gastro-waste can be processed, for example, at biogas stations; however, raising awareness and law enforcement are needed to ensure the discipline of producers in waste separation.

# CONCLUSION

The topic of determining production and preventing the creation of food waste is currently being addressed within the project SS02030008 "*Environmental Research Centre: Waste and Recycling Management and Environmental Safety (CEVOOH)*", where we are preparing a methodology for measuring food waste in close cooperation with the Ministry of the Environment. Our finding so far is that obtaining reliable data from the first three stages of the food chain is very problematic. We were basically not allowed into production areas for direct measurement, and the questionnaire survey carried out for the stages of the food chain: primary production and processing and manufacturing has a low success rate and little informative value. These conclusions are also confirmed by other studies conducted under the auspices of the Ministry of Agriculture, as well as foreign research. The only possibility of obtaining usable data are weight balances and data from other Czech and foreign studies and scientific papers, or the introduction of reporting obligations by amending existing legislation. From the point of view of accurate analysis of the amount and composition of food waste, we achieved the best results thanks to our own analyses of waste from canteens, biodegradable waste and mixed municipal waste, i.e. for the stages of the food chain of restaurants and food services and households. For the fourth and fifth stage, this method of monitoring is applicable and satisfactory.

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# A review article of Rapid Small-Scale Column Tests

**ANNA KÓLOVÁ, LADA STEJSKALOVÁ**

**Keywords:** adsorption — activated carbon — micropollutants — rapid small-scale column tests — RSSCTs


## SUMMARY

Rapid Small-Scale Column Tests (RSSCTs) can be used for quick and simple laboratory verification of the adsorption efficiencies of micropollutants on various adsorbents. The selection of adsorbent is the most important aspect when incorporating adsorption technology into the operation of a drinking water purification plant or a wastewater treatment plant. The tests are carried out at a laboratory-scale, which minimizes costs for materials and operation. This article focuses on the adsorption on granular activated carbon (GAC), as it is the most commonly used type of adsorbent. However, other types of adsorbents can be used for RSSCTs. The aim of this article is to introduce the reader to the issue of RSSCTs. The article specifically states the possible purposes of using RSSCTs and defines important parameters in the field of micropollutant adsorption testing on activated carbon which is applied in the dimensioning of tests and in their subsequent evaluation. The article also provides summary information on test methodology. The analysis of mostly foreign literature reveals that RSSCTs methodologies in individual studies show various modifications; however, essentially it is the same procedure. The differences are evident at the level of material equipment, construction dimensions, and setting parameter values; this is mostly due to different purposes of testing.


## INTRODUCTION

Rapid Small-Scale Column Tests (RSSCTs) are tests that examine the adsorption of micropollutants on a selected adsorbent. The principle of the method is the flow rate of test water through a small column filled with adsorbent, which allows more representative data to be obtained than in batch tests [1]. RSSCTs methodology was developed in the 1980s [2] as a scaled-down version of pilot testing in large granular activated carbon (GAC) columns [3]. RSSCTs are advantageous for minimizing time and economic demands compared to field tests. Their use significantly reduces the amount of material required for construction of the columns, amount of adsorbent, volume of water, and test operating time [4]. GAC is mostly used as an adsorbent, mainly due to its excellent adsorption capabilities and its wide availability on the market. However, other adsorbents can also be tested.

Other options can be chosen for testing micropollutant sorption on GAC, including pilot testing, which takes place in large columns. The difference compared to RSSCTs is that pilot tests can be used directly at the site of interest and testing usually takes place over a long period of time. Another possibility is mathematical and statistical predictive models [2]. Unlike predictive models, RSSCTs do not require extensive isothermal or kinetic studies [3].

RSSCTs can be used for many purposes. Previous studies with RSSCTs have focused on testing different adsorption media to remove a specific element from water (e.g., arsenic adsorption [5]), a specific organic substance (MTBE adsorption [6], geosmin adsorption [7]), or a mixture of substances (adsorption of pharmaceuticals and their metabolites [8], PFAS adsorption [9]). Other useful information can be found at a smaller laboratory scale. RSSCTs can be used, for example, to examine the effect of operating parameters on adsorption efficiency, such as EBCT (Empty Bed Contact Time), or they can be used to obtain breakthrough curves of individual micropollutants [5, 10]. Breakthrough curves are a graphical representation of the dependence of the monitored micropollutant concentration on the effluent from the column to the micropollutant concentration on the inflow to the column per unit of time [11]. Using RSSCTs, breakthrough curves can be obtained in a fraction of the time compared to large-scale testing [4]. RSSCTs are often the most appropriate way to evaluate different types of GAC for a given site (especially specific treated water). They can also quickly verify the manufacturer's claims and get an idea of the economic costs of adsorption and select the appropriate type of GAC for pilot testing [3, 10].

Accurate prediction of GAC effectiveness is particularly important for selecting the appropriate type of GAC for both field studies and real operation [12]. The parameters commonly reported by activated carbon manufacturers, such as iodine value, dechlorination half-value, BET isotherm, etc., give little indication of how a given type of GAC will behave in real conditions and to what extent the specific micropollutants will bind to it [6]. Therefore, it is advisable to test the type first in the laboratory. A constant or proportional diffusivity model is used for subsequent conversion from laboratory scale to field and operational filter size [2]. Using constant diffusivity design, we assume that diffusivity of the adsorbed substance is independent of adsorbent particle size [6, 8, 9]. Using the proportional diffusivity equation, on the other hand, we assume that intraparticle diffusivity is linearly dependent on adsorbent particle size [2, 13]. Computer models can be used to determine parameter values and breakthrough curves, e.g., FAST 2.0 software [8].

### Important parameters

In testing adsorption on activated carbon, as well as on other adsorbents, there are important parameters that must be taken into account when dimensioning the test. These parameters also facilitate interpretation of results and allow comparison of results from different studies. The most commonly used include EBCT, flow, and HLR, but other parameters may be useful as well. Below are some selected ones [8, 9,13]:

— **Empty Bed Contact Time EBCT**
The EBCT indicator is defined as the time for which flowing water is retained in the column volume occupied by GAC. EBCT is given in minutes or seconds and depends on the height of the GAC layer and selected filtration rate. The EBCT value is based on filter size design as well as estimated amount of GAC used. The EBCT value also affects breakthrough curves of the monitored pollutant, which may affect GAC service life. Higher EBCT values, i.e., higher contact time (retention), generally increase adsorption efficiency.

$$\text{EBCT} = \frac{V_B}{Q} \quad \text{or} \quad \text{EBCT} = \frac{L_B}{Q/A} = \frac{L_B}{HLR}$$

where $V_B$ is filter volume [m$^3$]
$Q$ flow rate [m$^3$.s$^{-1}$]
$L_B$ filter height [m]
$HLR$ hydraulic load [m.s$^{-1}$]
$A$ column cross section [m$^2$]

— **Flow Rate Q**
The flow rate, i.e., volume of water that flows through the column per unit of time, can be calculated (in addition to the basic formula), for example, by deriving it from the EBCT or HLR equation. The flow rate is most often stated in m$^3$.s$^{-1}$ or m$^3$.day$^{-1}$. However, on a reduced rapid test scale, it is commonly stated in ml.min$^{-1}$.

$$Q = \frac{V}{t}$$

where $V$ is volume of water [ml]
$t$ time [min]

— **Hydraulic Loading Rate HLR**
Another important characteristic is hydraulic loading rate, i.e., the flow rate divided by the area of the column [10]. The term Filter Velocities (vF), which corresponds to HLR, also appears in some literature. The unit m.h$^{-1}$ and then cm.min$^{-1}$ are most often used for this parameter.

$$\text{HLR} = \frac{Q}{A}$$

where $Q$ is flow rate [m$^3$.h$^{-1}$]
$A$ column cross section [m$^2$]

— **Filter Operation Time $t_F$**
This indicates the time from the start of the test to its end or to replacement of the activated carbon by regenerated or new activated carbon. The parameter is mainly used for longer-term tests on a larger scale and is usually stated in days.

— **Throughput Volume $V_L$**
This is the volume of water that passes through the column during filter operation. The parameter is mainly used for longer-term tests on a larger scale.

$$V_L = Q * t_F$$

where $Q$ is flow rate [m$^3$.den$^{-1}$]
$t_F$ filter operation time [days]

— **Bed Volume BV**
This parameter is dimensionless and is a standardization of the volume of water flowing to the volume of the activated carbon bed. It can be expressed mathematically as the ratio of the volume of water flowed to the volume of GAC in the column (filter volume). However, it can also be defined as the ratio between test operating time and EBCT.

$$\text{BV} = \frac{V_L}{V_B} = \frac{t_F}{EBCT}$$

where $V_L$ is Throughput Volume
$V_B$ filter volume

— **CUR (Carbon Usage Rate)**
This indicator defines GAC service life. It can be understood as the need for a certain amount of activated carbon in order to reach the target concentration for the monitored micropollutant. The unit is kg.m$^{-3}$.

$$\text{CUR} = \frac{M_{GAU}}{Q * t_{BK}}$$

where $M_{GAU}$ is GAC weight [kg]
$Q$ flow rate [m$^3$.s$^{-1}$ ]
$t_{BK}$ time taken to reach the specified target (or limit) pollutant concentrations at the GAC effluent [days]

## RSSCTs METHODOLOGY IN THE LITERATURE

The studies performed are diverse in terms of research purpose, which is also reflected in differences in methodology. However, it is basically a similar procedure – the flow of test water through the column. They differ from each other mainly in the subject of testing, design dimensions, amount of adsorbent used, or parameter values [5].

Model water can be chosen for testing, i.e. an artificially prepared solution with a known concentration of test substance, which will decrease by passing through the columns. Model water is useful in understanding certain basic adsorption relationships [6]. The use of actual drinking or wastewater allows assessment of adsorbent suitability for specific future uses. When using wastewater, it is advisable to first remove undissolved substances in order to avoid clogging of the adsorbent in the column. After mechanical and biological treatment, wastewater can be, for example, filtered through an ultrafiltration membrane [15]; however, standard laboratory filter paper will suffice.

The preparation of test columns is a basic step in RSSCTs preparation. The number of columns selected and their size, as well as the number of test repeats, reflect the purpose and scope of intended testing. Borosilicate glass is often used to make columns. Column dimensions vary greatly from study to study. Inside diameter ranges from 6 mm to 76 mm, and column length (height) from 100 to 750 mm. In some studies, only column diameter is shown. An overview of column dimensions is shown in *Tab. 1*.

The size of GAC fraction was also different in each study. Activated carbon can be used without treatment, or it can be crushed, ground, and then sieved to form a fraction of the desired size [5, 15, 16]. For example, a ball grinder can be used for grinding. GAC fractionation can be achieved using several nets with different mesh sizes [17]. After crushing, it is advisable to wash the fraction to remove excess dust, and then dry the GAC (at 105° C) and store it in a desiccator until use [1, 17]. GAC can be used without additional modification as supplied by the manufacturer [18]. In some studies, one average GAC fraction size is reported [1, 4, 15], in others a range of sizes is used to possibly increase adsorption rate [6, 7, 15]. Average particle size can be determined using a light microscope [17]. Details of GAC particle size occurring in the available literature are shown in *Tab. 2.*

In addition to the adsorbent itself, the column is filled with other components. The most common method in the studies is filling the glass column with a layer of glass balls and glass wool above and below the bed with GAC *(Fig. 1, 2).* Glass balls (1–3 mm) and glass wool are mainly used to fix activated carbon [1, 5, 8, 15]. In some studies, fine sand (0.45–0.55 mm particles) [7], glass balls of different diameters [16], or glass balls supplemented with a membrane PFTE filter (80–120 µm) [17] are used for a similar purpose. Ezzati et al. [19] report that they washed glass wool with acid before the columns were constructed to prevent microbial growth. Other necessary equipment are suitable column closures, hoses for conducting the test water into the column, and throttle clamps for regulating the outflow from the column and a stand for the entire apparatus. The columns can be mounted either in a laboratory stand, or in a specially designed stand [2].

Prior to the actual test, it is advisable to first rinse the assembled and sealed glass column containing GAC with distilled or deionized water (at least 15 minutes) to detect any leaks and design problems. This step also allows the medium to be compacted and incorporated inside the column [5]. In their study, Cantoni et al. [9] had the columns incorporated with deionized water for two hours. However, most studies report shorter periods. It has also been suggested that GAC in columns should be incorporated directly with the test water [2]. However, the incorporation of GAC can also be done in another way, e.g. according to the recommendation of the manufacturer of a specific GAC [18].

Test water can flow freely through the column by gravity; however, more often the water is driven by a pump [11]. Piston and peristaltic pumps are suitable for RSSCTs, which usually use lower flow rates. The values of the achieved parameters, including flow rates, are shown in *Tab. 3.* The values of the parameters, amount of GAC used, and design dimensions of the columns are interdependent. A very important parameter is EBCT, which some studies developed in more detail and examined its effect on the adsorption of various micropollutants (by including several EBCT values) [6, 18].

*Tab. 1. Column dimensions reported in RSSCTs studies*

| Column dimensions | Value | Unit | Source |
|---|---|---|---|
| Diameter | 6 | [mm] | [13] |
| | 7 | | [9, 15] |
| | 8 | | [8] |
| | 10 | | [17, 19] |
| | 11 | | [4, 5, 20] |
| | 44 | | [18] |
| | 76 | | [7] |
| Length (height) | 100 | [mm] | [19] |
| | 200 | | [19] |
| | 300 | | [21] |
| | 305 | | [1, 5] |
| | 400 | | [19] |
| | 750 | | [18] |

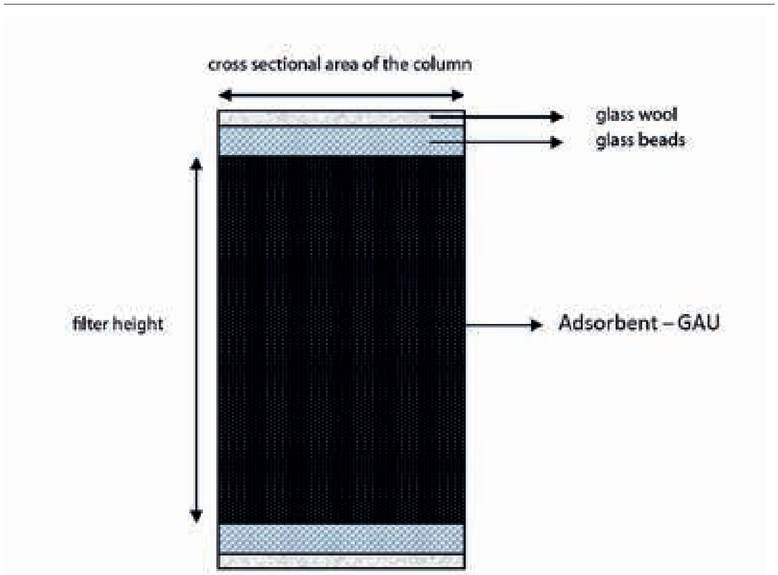


*Fig. 1. Scheme of filled glass column (author: Anna Kólová)*

*Fig. 2. Photo of glass column filled with GAC during the testing (author: Anna Kólová)*

The method and frequency of sampling depends on the length and purpose of the test. In some studies, automatic samplers were used for sampling [9, 15]. In addition to concentrations of monitored pollutants, it is appropriate to determine some basic chemical indicators, such as A254, pH, COD [2], or to monitor the turbidity or temperature of samples [18] to further evaluate efficiency of adsorption on GAC.

RSSCTs usually last several hours; however, there are also cases where the test time was set for several days [9]. If the tests take longer, columns can be wrapped in an opaque material (e.g., aluminium foil) or placed in the dark to prevent negative effects of light, e.g. photodegradation of micropollutants or growth of microorganisms and algae [6, 13]. Long-term tests lose the advantage of test speed; however, reduced material and water consumption costs are still significant.

## CONCLUSION

RSSCTs are a suitable tool for rapidly obtaining results in the field of adsorption of micropollutants on a specific adsorption medium. They can be used for many different purposes, e.g. to initially verify the effectiveness of a particular GAC to remove micropollutants from water before its subsequent long-term use on a field scale, or to research adsorption principles. The great advantage of rapid tests is the saving of time and costs for the construction and operation of columns.

This article can serve as a guide to design one's own RSSCTs methodology. When designing it, the purpose of testing must be taken into account, from which will be derived the selected matrix (model or real water), adsorbent, test operation mode, number of columns and their filling (adsorbent, glass balls, glass wool), setting test parameters (Q, EBCT, HLR, amount of adsorbent), test operation time, sampling frequency, etc. As the studies analysis shows, rapid tests show considerable variability of performances and can be adapted to the particular research purpose and possibilities.

*Tab. 2. GAC parameters shown in RSSCTs studies*

| GAC parameters | Value | Unit | Source |
|---|---|---|---|
| Average particle size | 94.3 | [μm] | [13] |
| | 120 | | [15] |
| | 190.3 | | [17] |
| | 500 | | [4] |
| | 610 | | [1] |
| Particle size range | 75–90 | [μm] | [6] |
| | 90–140 | | [15] |
| | 125–250 | | [6] |
| | 750–950 | | [7] |

*Tab. 3. Values of selected parameters shown in studies on RSSCTs*

| Parameter | Value | Unit | Source |
|---|---|---|---|
| Bed depth (height of the GAC filter in the column) | 2 | [cm] | [8. 15] |
| | 6.3 | | [17] |
| | 16 | | [20] |
| | 25.8 | | [13] |
| Bed volume (GAC volume in the column) | 0.5 | [$cm^3$] | [8] |
| | 1 | | [8] |
| | 6.8 | | [4] |
| | 15 | | [20] |
| EBCT | 9 | [s] | [15] |
| | 21.6 | | [17] |
| | 27 | | [4] |
| | 30 | | [18] |
| | 60 | | [18] |
| | 120 | | [18] |
| | 138 | | [13] |
| | 240 | | [18] |
| | 312 | | [7] |
| | 600 | | [20] |
| Q | 1.5 | [$ml.min^{-1}$] | [20] |
| | 2–3 | | [21] |
| | 3.2 | | [13] |
| | 15 | | [4] |
| | 800 | | [7] |
| HLR | 0.89 | [$m.h^{-1}$] | [20] |
| | 0.36 | | [4] |
| | 6.6 | | [13] |
| | 8 | | [15] |
| | 10.5 | | [17] |

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# Citation analysis of VTEI

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**Keywords:** VTEI — citation analysis — Scopus — citations


## SUMMARY

The citation rate of a journal is considered an indicator of its quality. This study presents a citation analysis of the VTEI journal, published by the T. G. Masaryk Water Research Institute (hereinafter TGM WRI). The citation analysis was conducted to identify the countries and institutions of authors who cite articles published in VTEI and the subject areas in which articles published in VTEI are cited. The identification of citing articles was complicated by the wide range of forms of VTEI journal title notation, as well as errors in the Scopus database. Therefore, the search was performed in several steps and the search query was gradually expanded. Descriptive statistics methods and cluster analysis using VOSviewer software were used for the analyses. A total of 126 publications were searched in the Scopus database, but only 108 publications were included in the analysis. These 108 articles quoted 152 articles published in VTEI. The number of VTEI citations has increased from sporadic citations prior to 2009 to more than 20 citing publications in 2020 and more than 30 cited publications in 2021. The majority of citations were received by articles published in VTEI within the first six years of publication, and the citation rate for articles published between 2009 and 2021 is relatively even. Authors from 66 institutions in 16 countries, mainly in Europe, contributed to the citing publications. However, authors from the Czech Republic were dominantly involved in citations and, in many cases, these were authors of articles published in VTEI. The main areas where articles published in VTEI are cited are environmental sciences, specifically the impacts of climate change on water management and hydrology, and water quality assessment using the water footprint.


## INTRODUCTION

In 2021, the first citation analysis of the Vodohospodářské technicko-ekonomické informace journal (VTEI) was presented [1]. This analysis presented data on the number of citations of the VTEI journal; however, it did not deal with their more detailed analysis. Citation analysis is one of the basic bibliometric methods used, for example, in scientometrics, which enables measurement and thus mutual comparison in the field of science and research [2]. Citation analysis has been used to assess the quality of journals since the 1970s [3]. Citations of a journal serve as direct evidence of its prestige and quality [4], despite the fact that this indicator is controversial [5]. The basic citation indicator is the number of citations of a specific article, author or, in this case, journal. Simkin and Roychowdhury [6] analysed a number of citations and, based on the errors contained in them, estimated that authors read only 20 % of the works they cite. Additional indicators, such as H-index [7], G-index [8], and many others, refine the results of citation impact assessment using functions based on citation distribution [9] or functions to score articles according to "citation importance". Most of these indicators are based on the assumption that each citation has "equal weight", but this is generally not true. The Journal Impact Factor (JIF) is the best-known indicator for evaluating the importance of journals, which is based on dividing the total number of citations a journal receives over a two-year period by the number of articles it published in the same period [10].

Citation analysis can also be used to find answers to many other research questions, such as the structure of research teams [11], influence of frequently cited articles [12], differences in citation patterns in different fields of science [13], tracking self-citations [14] or hyper authorship [15], and collaborative networks [16]. The potential of citation analyses built on current data sources such as Scopus can only be limited by our ability to ask the right questions [17].

For citation analysis, standard bibliographic databases (Web of Science, Scopus, PubMed) are used and, in the age of Internet services, scientifically oriented indexing services (Google Scholar) and social networks (Research Gate, Academia.edu). Each of these sources has its advantages and disadvantages, and the possibilities of using them for citation analysis have been examined many times [18–20]. The two main bibliographic databases – Web of Science and Scopus – are still considered the most reliable sources of bibliographic data [21]. After all, these two bibliographic databases are also used as part of the science evaluation in the Czech Republic according to Methodology 17+. In its Core Collection, Web of Science contains more than 75 million records of articles published in approximately 21 000 journals, as well as books, chapters in them, and conference proceedings and papers in them [22]. Additional records can be found in specialized Web of Science databases. Scopus contains over 76 million records of scientific results originating from more than 39 000 journals, 120 000 conferences and 206 000 books [17].

In this study, an analysis of the citations of the VTEI journal in the Scopus bibliographic database was carried out in order to find out:

— What is the citation rate of articles in VTEI and which articles and authors are often cited?
— From which countries and institutions are the authors citing VTEI and what are the mutual links between them?
— In which areas of research are the articles published in VTEI applied?

## DATA AND METHODS

Elsevier's Scopus database was chosen for citation analysis. The reason was primarily a larger scope compared to the Web of Science Core Collection, and also a larger number of citations of the VTEI journal in 2021 [1]. Data collection was carried out in several steps, during which the search query was continuously expanded to include all citations of the VTEI journal. The number of ways to write the VTEI title in the Scopus database turned out to be problematic. In total, there are 43 forms of recording the title of the VTEI journal in the Scopus database. The abbreviation of the journal, i.e. "VTEI", was used most often (48 times). The full title of the journal in the form of "Vodohospodářské technicko-ekonomické

*Tab. 1. Articles incorrectly marked in Scopus as bilingual*

| Article language (language of abstract) | Language according to Scopus | Citing article |
|---|---|---|
| EN (EN/FR) | EN/FR | VLACH, P., SVOBODOVÁ, J., FISCHER, D. Stone Crayfish in the Czech Republic: How Does its Population Density Depend on Basic Chemical and Physical Properties of Water? *Knowledge and Management of Aquatic Ecosystems*. 2012, 407. Available from: doi: 10.1051/kmae/2012031 |
| CZ (CZ/EN) | CZ/EN | ŠAJER, J. Modelová interpretace výsledků měření mísící zóny v Labi pod vypouštěním z ČOV Hradec Králové. *Journal of Hydrology and Hydromechanics*. 2010, 58(2), p. 126–134. ISSN 1338-4333. Available from: doi: 10.2478/v10098-010-0012-2 |
| CZ (CZ/EN) | CZ/EN | ČAPKA, L., ZLÁMALOVÁ-GARGOŠOVÁ, H., VÁVROVÁ, M., URBÁNKOVÁ, L. Využití UV/Vis spektrofotometrie pro stanovení diklofenaku. *Chemické listy*. 2013, 107(7), p. 550–554. ISSN 1213-7103. Available from: http://www.chemicke-listy.cz/ojs3/index.php/chemicke-listy/article/view/649 |
| CZ (CZ/EN) | CZ/EN | ČAPKA, L., LACINA, P., VÁVROVÁ, M. Optimalizace extrakce pevnou fází vybraných nesteroidních protizánětlivých látek s využitím kapilární zónové elektroforézy. *Chemické listy*. 2012, 106(1), p. 30–35. ISSN 1213-7103. Available from: http://www.chemicke-listy.cz/ojs3/index.php/chemicke-listy/article/view/1011 |
| CZ (CZ/EN) | CZ/EN | DEMNEROVÁ, K. Mikrobiologická bezpečnost potravin: současné strategie pro efektivní kontrolu. *Chemické listy*. 2012, 106(10), p. 920–925. ISSN 1213-7103. Available from: http://www.chemicke-listy.cz/ojs3/index.php/chemicke-listy/article/view/832 |

informace" (Water management technical-economic information) was used 32 times. The hyphen in the connection "technicko-ekonomické" was omitted in five citations, of which the diacritics were also omitted in three cases. Omission of diacritics also occurred in the other three citations. The title was often corrupted, so it was possible to find, for example, "Vodohospodá řské", "Vodohospodárské" (6x), "Vodohospodáršké" (4x), or even "Vodohospodï¿½rskï¿½ Technicko-Ekonomickï¿½ Informace", while in two cases a completely wrong title was used – instead of "technicko-ekonomické informace" "technologicko-ekonomické informace". In the other 20 citations, a total of nine forms of shortening the full title were used. The combination of the abbreviation VTEI and the full title of the journal appeared in six citations. The translation of the title into English was used three times, but each time in a different form (The Water Management Technical and Economic Information Journal, Water management technical and economic informations, Water Management Technical and Economical Information Journal), and twice the English title combined with the abbreviation VTEI (again in different variants). Even for abbreviations of the English title, it was possible to find four variants, in a total of eight citations. In three cases, the abbreviation VTEI was associated with the journal Vodní hospodářství, with which VTEI was jointly published between 1999 and 2015 as part of a cooperation agreement [23]. During the first data collection, the search query used in the previous study [1] was applied. The resulting information was then exported to csv format and processed in a MS Excel spreadsheet. The author of the article checked which of the listed results actually cite the VTEI journal. In the event that the citing article contained more than 80 citations, which the Scopus database displays on its website, the actual original document was checked. If a cited document was indicated to be cited more than once in the Scopus database, it was also verified whether all these citing articles were included in the selection, and the search criteria was expanded as necessary.

The final data collection was carried out on 15 February 2022. The following query was used for the search: REF ("technicko-ekonomick* inf*") OR REF ("Vodohosp* techn*") OR REF ("Wat* manag* tech* econ * inf*") OR REF ("Wat* manag* tech* and econ* inf*") OR REF (vtei) OR REF ("Vodoh* Tech.-Ekon* Inf*"). As a result, 126 records were included in the analysis. Out of these 126 records found in the Scopus database, 18 records were eliminated that cited "bulletin technicko-ekonomických informací" (4x), "vtei.com" (3x), "vtei.edu.ua" (1x), "Virtually transparent epidermal imagery (VTEI)" (3x), "OBIS VTEI" (2x), and four other documents presenting technical-economic information, but not the VTEI journal. In one case (EID 2-s2.0-84907092087) there is an error in the Scopus metadata, which states that the work of the author "Vtei H" should be cited a total of 258 times in the Scopus database, but no further citations of this author or his/her works can be found there. The analysis thus included 108 records, which in 152 cases cite an article published in the VTEI journal.

For statistical data analysis, the following information was entered into the MS Excel spreadsheet:
- EID identifier of the citing article,
- DOI of the citing article,
- publication date of the citing article,
- form of the VTEI journal entry in the citing article,
- DOI of the cited article published in VTEI,
- publication date of the cited article,
- volume and issue of VTEI where the cited article was published,
- title of the cited article,
- information on whether any of the authors of the cited article were from TGM WRI,
- information on whether the cited article in VTEI has the same author as the citing article (auto-citation).

In the case of missing data on the cited article (usually the DOI, which was only added to the articles in 2020), these data were taken from the electronic versions of the articles available at https://www.vtei.cz.

Co-authorship analysis, keyword co-occurrence analysis, and author analysis were performed using VOSviewer version 1.6.17, a freely available computer program for constructing and viewing bibliometric maps [24]. Co-authorship refers to the publication of an article prepared jointly by networks of researchers, research centres, and institutions, or even countries. The so-called "co-occurrence" refers to the number of times terms appear in more than one publication [25]. VOSviewer uses a clustering technique called "VOS" (visualization of similarities) to identify networks of similar and dissimilar research objects [26]. VOSviewer creates maps that can be linked based on co-author-ship (multiple authors in one publication), co-occurrence (frequency of occurrence of two terms occurring next to each other in the text), citation (reference to a work in the references), bibliographic links (two works referring to a third work in their bibliographies), or a link to a joint citation (links connecting two works cited by a third) [25]. For analyses using SW VOSviewer, diacritics were removed in the exported csv file and authors' names were corrected if the export was inaccurate. Furthermore, due to an unidentified error in data interpretation by the VOSviewer program, the name "Czech Republic" was changed to "Czechia" and the names of the institutions were modified to contain only the name or abbreviation of the name of the institution, and for foreign institutions also the country. If there was an institution in the exported file with different forms of name entry, all these variants were unified, while individual workplaces, faculties, and institutes were not specified. For visualization in SW VOSviewer, so-called overlay maps were used, which display dependencies using coloured groups known as node clusters. Nodes represent authors, institutions, countries or keywords, and the colour represents the average year the article was published. Node size for authors, institutions, and countries is based on the number of published papers, references, and the reference strength of an individual author, institution, or country. For keywords, the co-occurrence of the term in published documents and the reference strength determine the size of a node. Some nodes are close together or even clustered together, while others are further apart and even contain small clusters of their own. The closer the individual nodes are, the stronger the relationship between them.

# RESULTS AND DISCUSSION

## Number of citations

Despite the expansion of the search query, compared to the study from 2021 [1], there was an increase in the number of articles before 2020 by only three citations. However, the number of citing (from 13 to 21) and cited (from 22 to 33) articles increased more significantly in 2020, partly due to the expansion of the search query and partly due to the fact that the data collection for the year 2020 for the previous study [1] took place as early as on 1 January 2021, and therefore it could not include records that appeared in the Scopus database with a certain delay. For that reason, it can be assumed that even the data on citations in 2021 shown in *Fig. 1* may not be definite and there may be a slight increase in their number. In the same way, other forms of writing the title of the VTEI journal can be identified (see below), which will increase the number of cited articles. However, it can be stated that prior to 2009, articles in VTEI were only sporadically cited. Since 2009, it has been cited every year.

Of the 108 citing articles, 85 were journal articles ("article" type), 13 conference papers, 5 "review" type papers, 4 book chapters, and 1 note ("note" type). From the language point of view, 102 papers were included in the English language, eight of them were in Czech, and one paper each represented French, Polish, and Russian, while in the case of the "French" article it was actually an article in English with a French abstract. Similarly, four out of eight articles in Czech were marked as "bilingual" thanks to the English abstract (*Tab. 1*).

Articles citing the VTEI journal are most often published in the Swiss journal Water, published by MDPI (nine articles), four citing articles were published in the Czech journals Geografie – Sborník ČGS, and in Waste Forum and the Slovak Journal of Hydrology and Hydromechanics. Three articles were published in Chemické listy and in the IOP Conference Series Earth and Environmental Science. Other journals and proceedings published only one or two articles citing an article in VTEI.

## Age of citations

The average age of a citation is 4.5 years, but this value is given for interest only, as average values should not be used in cases where the underlying distribution is highly skewed and has a long tail [27]. A total of 86 % of the articles were cited within six years of their publication (*Fig. 2*). Half of the articles were cited within three years of publication, and articles cited within two years of publication account for a total of 36 % of citations. Compared to the general findings [13], there is a sharp decline in the number of citations for articles

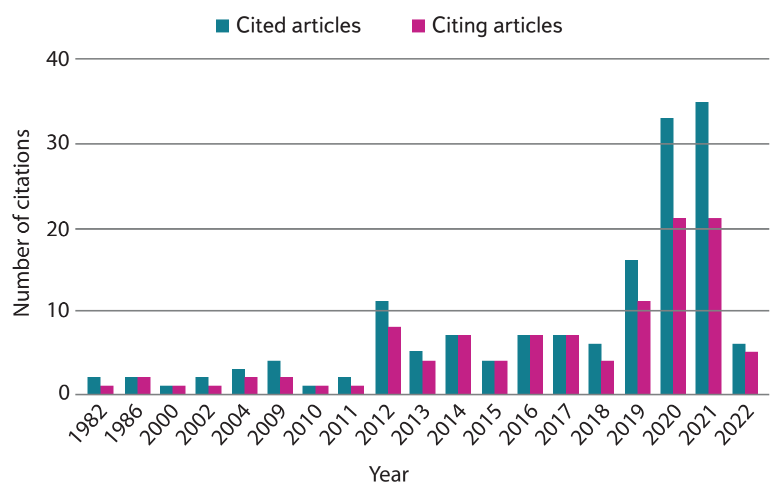


Fig. 1. Number of articles published in VTEI that have been cited in articles indexed in the Scopus database

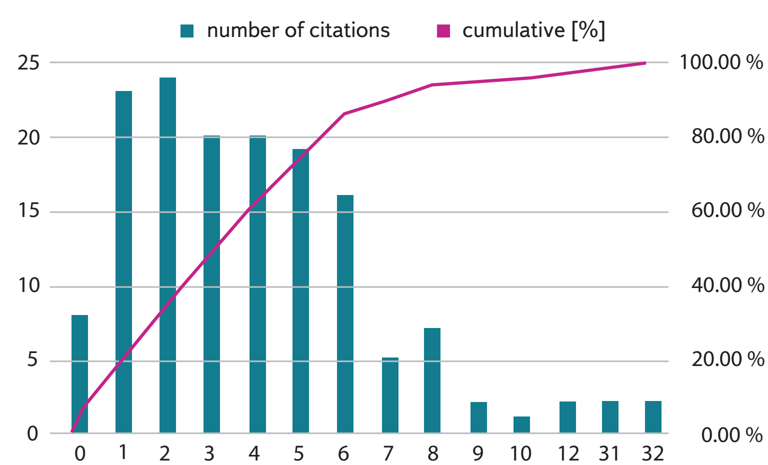


Fig. 2. Age of citations (difference between year of publication of the citing and the cited article)

older than six years. A possible explanation for this sharp decline is the fact that 152 received citations is still a relatively small number because different disciplines have different citation habits, which also change over time [28]. Rogers et al. [29] recommend a minimum sample size of 200 as an analytical minimum and 1000 samples for a good assessment of relative (but not absolute) citation performance. The sharp decline in the number of citations may also be due to the fact that articles published in VTEI before 2006 are cited sporadically (*Fig. 3*). However, we can also see that since 2009 there has been a relatively stable citation of approximately 10 articles each year, with the exception of 2012 and 2014, when articles received only four and one citation, respectively. On the opposite side of the spectrum, the year 2015 stands out, when the two most cited articles were published – the work of A. Vizina [30] with eight citations and S. Zahrádková [31] with seven citations. The year 2010 also stands out slightly, when an article by M. Váňa [32] was published, with five citations. 2021 and 2022 cannot yet be evaluated due to the insufficient time gap in the case of 2021, and for the fact that 2022 has not finished yet.

## Authors citing articles in VTEI

Of the 152 cited articles, 70 (i.e. 46 %) were cited by author teams in which at least one of the authors is a TGM WRI employee. A total of 344 authors from a total of 66 institutions and 16 countries participated in writing 108 citing articles. The 22 most active authors (with three or more articles) were divided into eight clusters and these authors participated in 36 citing articles. 13 of these authors are affiliated with TGM WRI (*Tab. 2*). The co-authorship map created by the VOSviewer program is in *Fig. 4*. Cooperation between organizations is shown in *Fig. 5*, international cooperation in *Fig. 6*. Authors from the Czech Republic contributed to 97 articles (i.e. 90 %) out of 108 citing articles (*Tab. 3*). This confirms the earlier finding that local journals are more often cited by local authors [33]. Non-English articles also generally receive fewer citations [33, 34]. Kirchik et al. [35] showed, using the example of Russian authors, that even local authors publishing in foreign (mainly English-language) journals tend to cite articles in local languages less than when they write an article for a journal in the local language.

Of the 152 cited articles, 59 (i.e. 39 %) were self-cited by one of the authors of the cited article. Self-citations were used in 40 (i.e. 37 %) citing articles. Self-citations are not inherently problematic, as there are many reasons for self-citations; for example, they can refer to an earlier experiment or place the article in the context of previous works [36]. Self-citations only become a problem when they are false or unsubstantiated. Szomszor et al. [37] list a number of studies that deal with the issue of self-citations. They also designed a graphic procedure for identifying excessive self-citations, but at the same time pointed out the need for professional interpretation of individual citation profiles. A detailed analysis of self-citations was therefore not the subject of this study.

## Research areas in which articles published in VTEI are cited

Classification of journals in which articles citing VTEI are published into research areas according to the Scopus database is shown in *Tab. 4*. The classification of individual articles that cite VTEI was carried out using keyword analysis. Keyword analysis of citing articles can identify research areas in which articles published in the VTEI journal are applied, reveal the internal relationship between research contents, and reveal the general direction of research. In addition to keyword analysis, it is possible to study the content of articles using text analysis of their titles, abstracts, or the text of the publications themselves. A total of 11 keywords were used 3 times or more in citing articles.

*Tab. 2. Most active authors citing papers in VTEI journal*

| Author | Cluster | Number of articles | Affiliation to WRI TGM |
|---|---|---|---|
| Vizina, A. | 1 | 9 | yes |
| Hanel, M. | 1 | 8 | yes |
| Beran, A. | 1 | 3 | yes |
| Nesládková, M. | 1 | 3 | yes |
| Máca, P. | 2 | 4 | no |
| Trnka, M. | 2 | 4 | no |
| Balek, J. | 2 | 3 | no |
| Semerádová, D. | 2 | 3 | no |
| Ansorge, L. | 3 | 9 | yes |
| Stejskalová, L. | 3 | 6 | yes |
| Dlabal, J. | 3 | 5 | yes |
| Datry, T. | 4 | 3 | no |
| Pařil, P. | 4 | 3 | yes |
| Polášek, M. | 4 | 3 | yes |
| Rozkošný, M. | 5 | 5 | yes |
| Hudcová, H. | 5 | 3 | yes |
| Sedláček, P. | 5 | 3 | yes |
| Dlouhá, D. | 6 | 3 | no |
| Dubovský, V. | 6 | 3 | no |
| Frajer, J. | 7 | 3 | no |
| Kopp, J. | 7 | 3 | no |
| Blažková, Š. | 8 | 3 | yes |

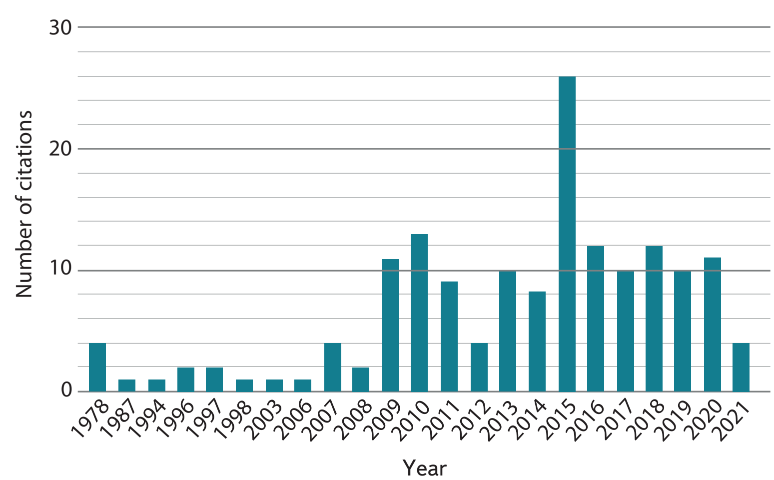

Fig. 3. Number of citations of articles published in VTEI in the relevant year

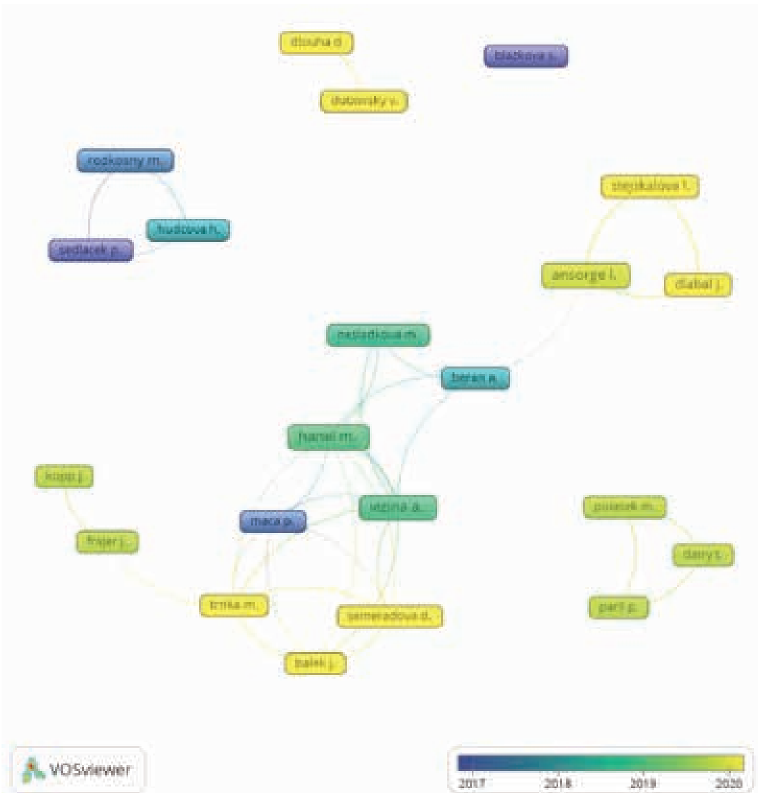


Fig. 4. Map of co-authorship who have cited the VTEI journal in at least three articles indexed in the Scopus database

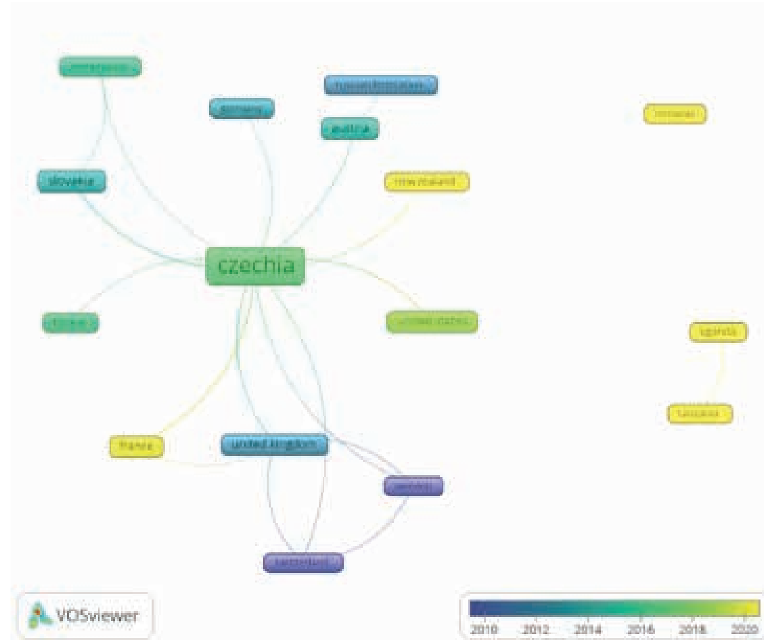


Fig. 6. Map of international collaboration on articles indexed in the Scopus database that cite articles published in VTEI

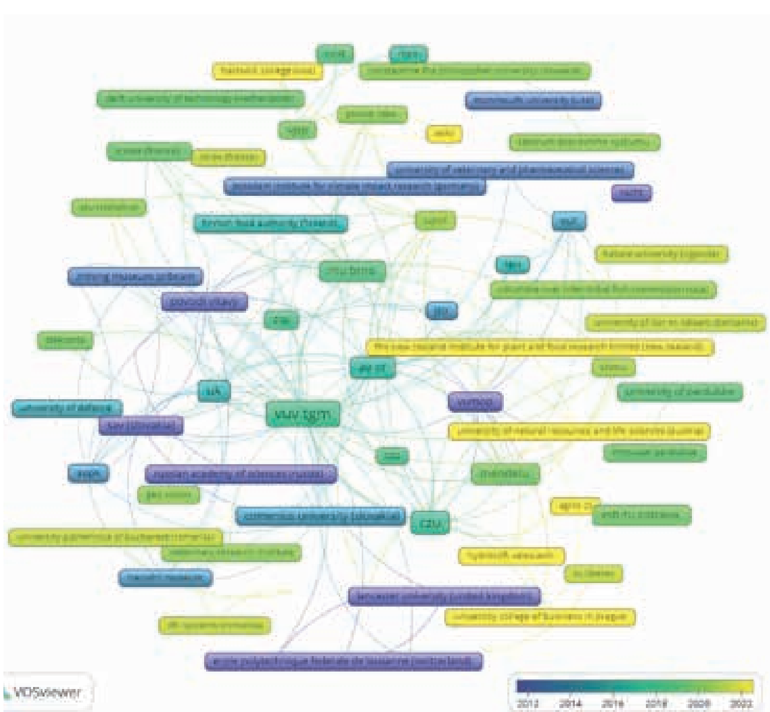


Fig. 5. Map of collaboration between institutions on articles indexed in the Scopus database that cite articles published in VTEI

*Tab. 3. International cooperation on articles citing papers in VTEI journal*

| Country | Cluster | Number of articles |
|---|---|---|
| Czechia | 1 | 97 |
| Finland | 1 | 1 |
| Germany | 1 | 1 |
| Sweden | 2 | 2 |
| Switzerland | 2 | 2 |
| United Kingdom | 2 | 3 |
| Austria | 3 | 3 |
| Russian Federation | 3 | 2 |
| Netherlands | 4 | 2 |
| Slovakia | 4 | 7 |
| Tanzania | 5 | 1 |
| Uganda | 5 | 1 |
| New Zealand | 6 | 1 |
| Romania | 7 | 1 |
| France | 8 | 3 |
| United States | 9 | 3 |

*Tab. 4. Classification of citing articles into research areas according to Scopus*

| Scopus subject area | Number of articles |
|---|---|
| Environmental science | 67 |
| Agricultural and biological sciences | 37 |
| Social sciences | 32 |
| Earth and planetary sciences | 25 |
| Engineering | 16 |
| Biochemistry, genetics and molecular biology | 14 |
| Energy | 6 |
| Chemical engineering | 5 |
| Chemistry | 4 |
| Decision sciences | 4 |
| Medicine | 4 |
| Arts and humanities | 3 |
| Business, management and accounting | 2 |
| Mathematics | 2 |
| Computer science | 1 |
| Economics, econometrics and finance | 1 |
| Materials science | 1 |
| Neuroscience | 1 |
| Pharmacology, toxicology and pharmaceutics | 1 |
| Physics and astronomy | 1 |

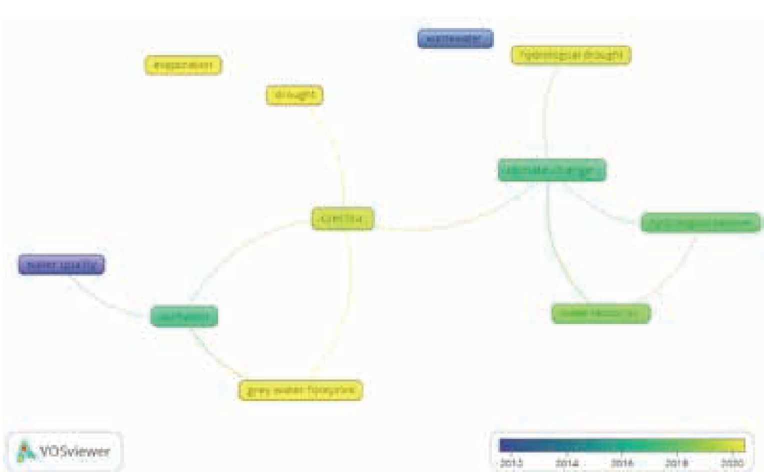


Fig. 7. Map of keywords co-occurrence (note: the map was created after the term "Czech Republic" was replaced by "Czechia")

*Tab. 5. Keyword co-occurrence*

| Keyword | Cluster | Occurrence |
|---|---|---|
| Climate change | 1 | 9 |
| Hydrological balance | 1 | 3 |
| Hydrological drought | 1 | 3 |
| Water resources | 1 | 3 |
| Grey water footprint | 2 | 5 |
| Pollution | 2 | 5 |
| Water quality | 2 | 5 |
| Czech Republic/ Czechia | 3 | 8 |
| Drought | 3 | 3 |
| Evaporation | 4 | 3 |
| Wastewater | 5 | 3 |

The keyword "climate change" was used most often (9 times) (*Tab. 5*). The key word map is shown in *Fig. 6*. It clearly shows that the cited VTEI articles mainly focus on two research areas. The first is the issue of climate change and hydrological extremes (especially drought), i.e. an area that has a direct impact on the availability of water resources. The second is the area dedicated to water pollution and its assessment, e.g. using the water footprint. These findings are not surprising considering which authors most frequently cite articles published in VTEI. They are Adam Vizina and Libor Ansorge (both with nine citations of articles in VTEI), while the team around A. Vizina is focused on hydrological research and the team of L. Ansorge on water footprint research.

## CONCLUSION

The analysis focused on the citation rate of articles published in VTEI in journals indexed in the Scopus database. As of 15 February 2022, a total of 152 citations of articles published in VTEI were found, which cited a total of 108 articles indexed in the Scopus database. The analysis of citations is especially complicated by the use of different variants of notation, and sometimes even the wrong notation of the title of the journal. Articles in VTEI have been cited by authors from 66 institutions from 16 countries. However, the majority of citations were from teams of which at least one author came from the Czech Republic and often from TGM WRI, the publisher of the VTEI journal (46 %).

From the point of view of the distribution of citations over time, three periods can be distinguished. Before 2009, articles published in VTEI are cited sporadically. After 2009, articles published in VTEI are cited regularly, while since 2018 an increased number of citations is noticeable. In 2020 and 2021, the number of cited articles exceeds 30 per year. Articles receive the majority of citations (86 %) within six years of publication.

The analysis showed that the VTEI journal is among the sources of professional information for a number of scientific teams, and not only in the Czech Republic.

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RNDr. Dana Baudišová, Ph.D., graduated in General Biology at the Faculty of Science of Charles University in 1988, and in 2000 she completed her doctoral studies in microbiology at the same Faculty. Starting in 1993, she worked at TGM WRI, p. r. i., for 23 years, dealing with water microbiology (methods of microbiological analyses; microbial contamination of surface water and wastewater; research of microbial pollution, its sources and elimination). Since 2018, she has been working in the Water Hygiene Department of National Institute of Public Health, focusing on microbiology of drinking, bathing, and recycled water.


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Mgr. Marek Havlicek, Ph.D., graduated from the Faculty of Science of Masaryk University, field Physical Geography. From 2001 to 2007 he worked at the Nature Conservation Agency of the Czech Republic, a branch in Brno. Since 2007 he has worked at the Brno branch of VÚKOZ, p. r. i., in the Department of Landscape Ecology as a researcher, since 2013 he has also worked at Transport Research Centre. It focuses mainly on the evaluation of long-term changes in land use, historical development of water areas, green landscape infrastructure, transport and environment and other landscape-ecological topics. He is the author and co-author of a numerous of publications in international and national journals, several monographs, certified methodologies and specialized maps. He is the co-researcher and co-researcher of research and commercial projects, cooperates with experts from other scientific institutions, universities, government representatives and the public.


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Mgr. Silvie Semerádová studied cartography and geoinformatics at the Faculty of Science, Charles University in Prague. Since 2005, she has been working at TGM WRI, p. r. i., at the Department of Hydroecological Information System, where she is involved in the management and updating of data sets and the operation and development of the system. Since 2008, she has been dealing with the Water Framework Directive and reporting of data sets to European systems. During the preparation of documents for reporting emissions to the aquatic environment, the need arose to expand the database, which led to participation in several projects aimed at this topic. She also deals with emissions issues as an external expert at the European Topic Centre on Inland, Coastal and Marine Water for the European Environmental Agency.


## Ing. Dagmar Vološinová
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Ing. Dagmar Vološinová has been a TGM WRI, p. r. i., employee since 2002. She graduated from the Faculty of Agronomy of the Czech University of Life Sciences in Prague. As part of her work at Centrum pro hospodaření s odpady (Centre for Waste Management, CeHO), she deals with the issue of waste footprint, waste, and circular economy. At present, as the main researcher or co-researcher, she participates in projects on waste management, especially food, municipal and construction-demolition waste in the Czech Republic and


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Ing. Anna Kólová has been an employee of the Department of Water Management and Wastewater Treatment at TGM WRI, p. r. i., since 2018. In the same year, she completed a master's degree in the Protection and Utilization of Natural Resources at the Faculty of Agrobiology, Food and Natural Resources at the Czech University of Life Sciences. She focuses mainly on the possibilities of wastewater treatment of specific micropollutants, which conventional treatment processes are not able to effectively eliminate. In this area, she deals mainly with the possibility of adsorption of micropollutants on granular activated carbon.


## Ing. Libor Ansorge, Ph.D.
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Libor Ansorge, PhD, has been an employee of TGM WRI, p. r. i., since 2011, and since 2018 he has been Deputy Director for Research and Professional Activities. In 1997 he completed his Master's degree at the Faculty of Civil Engineering of the Czech Technical University in Prague, majoring in Water Management and Water Structures, and in 2017 at the same Faculty, he completed a doctoral study programme in Environmental Engineering. Within his profession, he deals with a wide range of issues related to water use, focusing on future water needs for society and environmental assessment of water use such as water footprint assessment. He has participated in several research projects as a principal investigator or member of research team.

# Interview with Dr. Yelizaveta Chernysh, a new Ukrainian researcher at TGM WRI

**Doctor, we know that in Ukraine you worked as a researcher focusing on wastewater and waste as such. Can you briefly describe your experience?**

I have 10-years' experience in research related to wastewater and sludge treatment and a long-standing collaboration in this area in Sumy region (Ukraine).

I previously dealt with the basic stages of anaerobic digestion of sewage sludge and phosphogypsum waste under bio-sulfidogenic conditions and the effects of ozone pretreatment on the biodegradability of sewage sludge. The result of my work was, for example, a finding that the use of sludge pre-treatments prior to the anaerobic digestion process leads to an increase in organic matter removal under mesophilic conditions. My dissertation thesis *"Scientific basis of the ecological-synergetic approach to the process of phosphogypsum utilization to reduce the anthropogenic load on the environment"* also covered these topics.

I also serve as director of the International Innovation and Applied Center "Aquatic Artery" in Sumy region, which develops cooperation in the field of water protection and wastewater recycling.

**What issues have your last projects focused on?**

My research activity focuses on technologies and processes of environment protection, in particular the biotechnologies of waste recycling, with special attention being paid to the pre-treatment and utilization of waste/by-products for bioconversion with the production of bio-based products (biogas, bio-fertilizer, bio-sulphur, etc.). The sphere of my scientific interests also comprises the theoretical and practical aspects of the synergetic concept of nonlinear ecosystems processes, which include the estimation of anthropogenic impact.

Among the projects related to this area, I can mention, for example, a grant for the multidisciplinary research team *"Bioenergy processes of waste recycling"*, or a joint Ukrainian-Czech project *"Bioenergy innovations in waste recycling and rational use of natural resources"*.

**Before you were forced to leave Ukraine, did the situation in your city allow you and your co-workers to continue their work, at least in part, or was it necessary to stop working on your projects altogether?**

Before I left Sumy in March 2022, there was a university holiday due to the difficult military situation.

**You have been in the Czech Republic for a short time. Of course, the first thing was to provide for yourself and your relatives basic needs, such as housing, and subsequently work. Therefore we would like to ask – how do you cooperate with the Czech team? Have you had the opportunity to apply your experience in one of the already running projects?**

The Czech team at the Institute treated me and my family very well. I am very grateful for their support. I am now involved as a researcher in the work of the Department of Water Supply and Wastewater Treatment, as well as in "Centrum Voda", and I hope that my experience will be in demand. We discussed the possibilities of developing a research network internationally, as well as applications to the Horizon Europe programme. I think that my activity in "Aquatic Artery" exactly overlaps with the international grant activity of "Centrum Voda".

**Is there a topic that could be submitted as a project in subsequent national calls in the Czech Republic and that you could work on even after returning to Ukraine?**

I think topics related to sewage sludge treatment and phosphogypsum processing (as their recycling is very important today around the world) can be developed both in the Czech Republic and Ukraine, both at the level of national competitions and in the context of grant applications at the EU level.

I am looking forward to fruitful work in your Institute as well as cooperation with the Czech University of Life Sciences Prague. I hope this cooperation can be continued and developed in the long term, even after my return to Ukraine.

*Thank you for your work for* TGM WRI *and for the time you devoted to our interview.*

**Editorial office VTEI**

## Dr. Yelizaveta Chernysh

Works at the Department of Ecology and Environmental Protection Technologies, Sumy State University (SSU, Ukraine) and currently also at T. G. Masaryk Water Research Institute. Yelizaveta Chernysh was born in 1987. After receiving a master's degree in Ecology and Environmental Protection (2010), she defended her doctoral thesis in Ecological safety in 2019 at SSU and received a Doctor of Technical Sciences degree (2020). In 2021, she received the academic title of Associate Professor in the Department of Ecology and Environmental Protection Technologies at SSU. Apart from SSU, she works as a director of the International Innovation and Applied Center "Aquatic Artery" in Sumy region (Ukraine). She has received a number of awards and foreign scholarships (Germany, France). She is a reviewer of many prestigious scientific publications and a member of several professional international organizations (e.g., Solid Waste Association of North America, and Hong Kong Chemical, Biological & Environmental Engineering Society). Currently she works as a researcher at TGM WRI in Prague and teaches at the Czech University of Life Sciences Prague.

Photo: 123RF.com

# Risk assessment as a comprehensive approach to protection of drinking water sources

Drinking water supply as well as its quality form one of the basic pillars of modern society. This corresponds to the goal of the International Water Association (IWA) – good, safe and drinkable water, which enjoys consumer confidence and can be not only drunk without fear, but in which the consumer also appreciates its taste and aesthetic appearance. In order to meet these objectives, it is important to set drinking water quality requirements and also to keep the whole process of drinking water production and distribution, including all risk areas, under continuous control. In 2004, the World Health Organization published a new concept based on comprehensive risk assessment and management, covering the entire supply system from the raw water source to the consumer's tap. This approach was called the "Water safety plan". Subsequently, Council Directive 98/83/EC on the quality of water intended for human consumption [1] was amended in 2015, where this risk-based approach was introduced. However, this amendment was not sufficient in view of modern needs. Therefore, a new EU Directive 2020/2184 on the quality of water intended for human consumption [2] was issued in December 2020. One of the major changes from the original version of the Directive is Article 8, which deals with the risk assessment and management of the catchment areas for abstraction points of water intended for human consumption. This Article, and its subsequent transposition into Czech legislation, will require considerable personnel, material and financial security, as it is a very specific and complex agenda. The need to analyze the current state of the database, propose additions, optimize procedures, and compile a methodology for the above-mentioned risk assessment and management is an important step for the successful implementation of Article 8 in practice.

In the 5th public tender "Programme for the Support of Applied Research, Experimental Development and Innovation in the Environment – Environment for Life" announced by the Technology Agency of the Czech Republic, the TGM WRI project *"Tools for risk assessment of the catchment areas for abstraction points of water intended for human consumption"* (SS05010210) was selected for support. This three-year project began in January 2022 and aims to create a methodological procedure and related database. EU Directive 2020/2184 on the quality of water intended for human consumption calls for a comprehensive risk-based approach to water safety, covering the entire supply chain from river basins of raw water abstraction, the actual abstraction, treatment and storage, to drinking water distribution to the end users. This risk assessment should build on the knowledge gained and measures taken in accordance with Directive 2000/60/EC of the European Parliament and of the Council [3] and take better account of aspects of the impacts of climate change on water resources. This approach should also aim to reduce the degree of treatment required to produce water for human consumption by identifying problem areas in the river basin point of abstraction and proposing remedial measures to improve the quality of the water abstracted. This comprehensive procedure will ensure a constant exchange of information between risk assessors, water suppliers, and competent authorities. In our project, risk assessment tools will be designed to be usable nationwide and to help implement the requirements of Article 8 of the 2020/2184 EU Directive in the Czech Republic. The main project outputs will be a methodology approved by the relevant state administration body (NmetS) describing the risk identification and assessment procedure, including a proposal for the effective use of nationally available data, and a specialized public database (S). More detailed information about the project can be found on its website (pitnavoda.vuv.cz).


Hostivař Reservoir, April 2019 (Photo: L. Jašíková)


Hostivař Reservoir, April 2019 (Photo: L. Jašíková)

## References

[1] *Směrnice Rady 98/83/ES o jakosti vody určené k lidské spotřebě.*

[2] *Směrnice Evropského parlamentu a Rady (EU) 2020/2184 o jakosti vody určené k lidské spotřebě* (přepracované znění).

[3] *Směrnice Evropského parlamentu a Rady 2000/60/EC ustavující rámec pro činnost Společenství v oblasti vodní politiky.*

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## LUŽICKÉ HORY (LUSATIAN MOUNTAINS)

In July 2010, a flash flood caused by a big summer storm washed the bed of the left-hand tributary of Studený potok down to the sandstone bedrock. The torrent of heavy water caused damage of millions of Czech crowns on forest land and in the village of Studený, where it uprooted trees, knocked down bridges, and washed away a piece of road.
*Text and photo by Václav Sojka, www.vaclavsojka.cz.*