Wastewater recycling and the possibility of its technical use in practice

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\textbf{Abstract.} In real practice, almost half of the water, after its technical or technological use in various degrees of pollution, is drained by sewerage systems to wastewater treatment plants and subsequently discharged into the recipients of rivers and streams. The current and especially the future method of urban and industrial wastewater treatment is at such a high level that the treated water, before its discharge into the recipients, has a higher degree of quality than the flowing surface water in the watercourse. Under these ever-improving conditions and possibilities, it is appropriate to use well-treated wastewater not only for the needs of agriculture, but also as an alternative supply of fire water for fire purposes. The dislocation of wastewater treatment plants (hereinafter WWTP) in territorial cadastres with safe access to the opened level of treated water allows its relatively rapid pumping at any time, especially in conditions where there is no other suitable natural or multipurpose source of fire water. The following article suggests in a basic way how to use the given options without the risk that the treated wastewater will not endanger the health of fire brigades or will not have the negative impact on the environment of the extinguished building and its surroundings in which the fire is extinguished.

1. Introduction

Water is one of the most important natural resources, which ensures the survival of animal and plant species, including humans. Fresh water consumption and demand have been rising over the years as a result of population growth, the intensification of agriculture and industry. At least until the end of the 21\textsuperscript{st} century can not be expected turnaround in the current global management of fresh water. The statement, nor other scientific forecasts do not give too much optimism in this area. One of the few truly realistic and quickly feasible ways to change this negative trend is the use of well-treated wastewater, which is an integral part of the consumption of the human population in the current way of dealing with drinking water.

An innovative technique for protecting aquatic ecosystems is the reuse of gray water, rainwater harvesting, seawater desalination and groundwater extraction, etc., especially in the face of climate change and climate variability are central in minimizing water scarcity. Reusing gray water as an alternative and efficient source of water can help reduce the pressure on fresh water. The level of acceptance is due to limited information or awareness programs. However, the strategy of water reuse and the motivation to use it is increasing. New possible ways need to be found to support the strategy of reusing recycled water while increasing environmental safety [1, 18].

One of the limiting current factors of using the wastewater for subsequent implementation for a number of options is the European and subsequently applied legislation of the Czech Republic in water law.
2. Requirements for the quality of raw water in the conditions of the Czech Republic

Indicators of water quality taken from surface water sources or groundwater sources for the purpose of treatment for drinking water and their limit values sets the Decree of the Ministry of Agriculture No. 428/2001 Coll., Which implements Act No. 274/2001 Coll., On water supply and sewerage for public use. According to the decree, raw surface or groundwater must meet the limit categories A1, A2, A3. Despite this statement, it will be necessary in the coming years, at least locally, to look for another way to obtain water for water systems. It is necessary to realize that water supply systems for public use are not only a supplier of drinking water to consumers, but at the same time, a multi-purpose source of fire water for built-up and undeveloped areas of the state.

For this reason, a number of institutions, including students of technical universities, are beginning to deal with this issue and ways of solving it. In the following text of the paper, one of the outputs of this research and the search for new ways to increase the supply of water for fire use will be presented for the professional and general public.

In the years 2017 to 2020, a study was carried out on the possible use of treated wastewater in the fire brigade of the Czech Republic. From time immemorial, wastewater has been considered unnecessary waste and is not suitable for further use. Historically, this approach has evolved through the removal of wastewater outside the inhabited area, to its concentration in one place - the WWTP, where this wastewater is safely treated and disposed of by discharge into the recipient [19].

Very demanding permits for the discharge of treated wastewater into recipients always stipulate that the quality of water discharged into the recipient must be at a higher level than the water in the recipient itself. Through the passage of contaminated water through the WWTP technology, its qualitative criteria are monitored at the outflow and must meet the criteria for discharged water in a permit issued by the relevant water authority. Physical (temperature, density), chemical (occurrence of individual elements) and biological (number of organisms, animals) indicators determine the quality of water for a given purpose of use and comparison of waters. Water quality is thus a set of properties (organoleptic, biological, chemical, etc.) of water, which can be expressed in layman's terms as water purity. For the purposes of this study, tests were performed in an accredited laboratory, which was Laboratory of the Olomouc Health Institute [2].

3. The course of the research study

In the first phase of the research study, physical and chemical indicators were monitored. Sampling from fire trucks was performed, as well as sampling from the Bečva River and a sample of wastewater from the WWTP. The samples taken were tested for qualitative indicators of COD, BOD, insoluble substances. Furthermore, this analysis was extended to ammoniacal nitrogen. The water samples were stored for two months in an environment simulating the environment of the firebrigade garage. The samples were stored in glass bottles or plastic sample boxes at a temperature of 18.5 °C without access to sunlight. They were then re-analyzed for COD, BOD, NL, N-NH₄. The result of the analysis shows Table 1.

Due to the sampling in the winter, when the outdoor temperature was around the freezing point, the sample from the river showed a qualitatively better result. However, these parameters do not have a significant effect on the decision-making process as to whether or not treated wastewater can be used.

| Table 1. Result of the analysis. |
|---------------------------------|
| Date analysis | Unit of measure | COD₅ | BOD₅ | insoluble substances | N-NH₄ |
|----------------|-----------------|------|------|----------------------|-------|
| MAN (specimen A) | 23/11/17 | mg/l | -------- | < 8.0 | < 1.5 | < 5.0 | < 0.02 |
| 05/02/18 | mg/l | 12.1 | < 1.5 | 23.2 | < 0.02 |
| WWTP (specimen B) | 23/11/17 | mg/l | 18.7 | < 1.5 | 40.0 | < 0.02 |
| 05/02/18 | mg/l | 18.7 | < 1.5 | 40.0 | < 0.02 |
| river Bečva in Přerov (specimen C) | 23/11/17 | mg/l | 12.1 | < 1.5 | 23.2 | < 0.02 |
| 05/02/18 | mg/l | 12.1 | < 1.5 | 23.2 | < 0.02 |
The next step, with a more pronounced effect on the intervening firefighter, was to verify the microbiological safety, where in general bacteria or viruses causing serious diseases such as typhus, infectious hepatitis or diarrheal diseases of viral origin can be transmitted by water. The analysis of these diseases would be technically, temporally and financially unbearable. The method of so-called indicators of faecal pollution is applied worldwide, in which bacteria living in the intestinal tract of humans and warm-blooded animals such as E. coli bacteria, coliform bacteria or enterococci are sought. If any of these bacteria are found in the water, the water is suspected of contact with feces or animal remains, so there is a presumption that it could contain pathogenic bacteria and viruses, which most often come from the intestinal tract. In addition to indicators of faecal contamination, so-called general contamination indicators (number of colonies growing at 22 °C or 36 °C, formerly so-called psychrophilic and mesophilic bacteria) are also used, which are of less hygienic importance than the previous one [3].

From the point of view of the protection of the intervening firefighter, it is necessary to look at this issue also from the angle of the possible health threat when using this water. Purified water can contain viruses, parasites or bacteria capable of attacking the human body and causing subsequent diseases. The view of the firefighter in this case can be two-sided, namely, the practical side and the legislative side.

Fire brigades routinely use water from natural sources, and none of the firefighters or fire commanders think about the quality or safety of this water. At the same time, the fact that water is transported under pressure to the place of combustion also plays an important role here. Effective jet spraying ranges from 9 meters to about 29 meters depending on the type of jet used [4]. Also, the exposure time is relatively short. When using this water without respiratory protection (eg liquidation of hidden foci in a forest fire), combustion products swirling using a water jet are much bigger threat than droplets or mist of this water [2].

We can also look at this issue on the basis of legislative regulations. Those that are closest to the use or handling of this water were selected, eg Act 238/2011 (bathing in the wild), NV 428/2001 (requirement for raw water quality) or also ČSN 75 7143 (water for irrigation) during emergency activities [5, 6, 7]. Subsequently, this procedure was consulted with the Olomouc Health Institute, when the requirements of the standards were extended by other items.

This follow-up study was similar to the previous study. Again, a water sample was taken from the WWTP, this time in the amount of 1000 liters with storage in the conditions of the exit garage of fire equipment with the prevention of access to light. An up-to-date analysis of the abstracted water was performed in the drinking water laboratory in Přerov and also an extended analysis in the health institute in Olomouc. The drinking water laboratory performed the analysis in the range of: coliform bacteria, E. coli, thermotolerant coliform bacteria Figure 1, partial enterococci, clostridium perfringens.

![Figure 1. Coliform bacteria and Enterococci](image-url)
Laboratory of the Olomouc Health Institute, in addition to the norms and the law, monitored the occurrence of Pseudomonas aeruginosa, Legionella spp, Salmonella Figure 2. The analyzes were performed from April onwards at an interval of two weeks. One month after the analysis in the interval of 3 months. In August, water was taken and subsequently analyzed from natural sources, specifically from the Bečva River and lake Laguna. The month of August was chosen due to the least favorable conditions in the quality of natural waters (long-lasting high temperatures). Due to the full objectivity of the performed measurement, samples from two fire tanks were added in November, namely the type of open fire tank and closed fire tank. The individual samples were then assessed mutually, see Table 2.

![Figure 2. Salomella sp. inoculated on Rambach agar [9].](image)

The measurements show that the water treated from the WWTP is significantly better in quality than water from natural sources. This fact applies to both cases of "freshly" pumped and long-term stored water from the WWTP. There is another possibility of using this water in storage. It is appropriate to consider the use of certain reservoirs with this water at fire stations to continuously replenish the capacity of tank cars.

**Table 2. Laboratory evaluation [2].**

| Parameter / Date | Wastewater treatment plant | Bečva shore | Bečva center | lake Laguna | company Meopta | Retirement home Radkova |
|------------------|---------------------------|-------------|--------------|-------------|-----------------|-------------------------|
| Coliform bacteria|                           | 10.4 30.4 17.5 8.8 10.11 | 8.8 8.8 8.8 8.8 10.11 | 10.11 10.11 | 78000 900 78 650 890 | 8200 8200 1260 7100 2200 |
| E. coli          |                           | 40 100 0 0 0 | 6400 380 290 0 0 | 0 0 0 0 0 | 3500 170 5 18 0 | 8800 590 450 150 0 |
| Thermotoler. bacteria |                  | 210 2 0 0 0 | 960 89 72 0 0 | 0 0 0 0 0 | 720 42 32 0 0 | 970 100 16 90 0 |
| Partial enterococci |                      | 210 2 0 0 0 | 960 89 72 0 0 | 0 0 0 0 0 | 720 42 32 0 0 | 970 100 16 90 0 |
| Clostridium perfrigens |                   | 720 42 32 0 0 | 970 100 16 90 0 | 0 0 0 0 0 | 720 42 32 0 0 | 970 100 16 90 0 |
| Pseudomonas aeruginosa |                    | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 |
| Legionella spp   |                           | 0 1 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 1 0 0 0 | 0 0 0 0 0 |
| Salmonella       |                           | neg Neg neg pozit pozit Neg Neg Neg | Neg Neg Neg Neg Neg | Neg Neg Neg Neg Neg | neg Neg neg pozit pozit Neg Neg Neg |

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4. Health risks of water-borne diseases

When assessing the health risk associated with workers' exposure to biological agents, the nature, extent and duration of exposure must be determined so that all risks to workers' health can be assessed and the necessary measures taken to protect their health. In the Czech Republic, a system of work categorization has been introduced in the hygiene service, i.e. also for work in waste management. The system divides work into four categories according to risk [13]. Biological factors are classified according to the degree of risk of infection into four groups (Section 22 of Government Decree No. 361/2007 Coll. [12], as amended, which lays down the conditions for protecting the health of employees at work).

The obligations and responsibilities of the employer to ensure safety and health at work are enshrined in the Labor Code. The main goal of ensuring safety and health at work is to analyze, evaluate and reduce risks to the lives and health of employees at work. The provisions of the Labor Code on safety and health at work are followed by implementing and other related regulations [14].

With the use of specified protective equipment, handling the wastewater should not cause health complications for those affected, apart from the possibility of a sensitive individual and compliance with the principles of hygiene. Contact with water itself is generally minimized and exposure is short. In case of reduced protection, eg when extinguishing forest stands, a respirator can be used for respiratory protection, eg FFP 2. However, if the intervening firefighter does not use respiratory protection, the risk of infection by inhaling the aerosol of sprayed water is very low, if we consider the spray distance and health resistance of the firefighter (apart from the fact of the current indisposition). The possibility of protection is also offered by the use of products such as Chloramine, Savo or Persteril. However, the use of these products can have a negative impact on the environment.

The results of the tested samples of treated wastewater also correspond to the values given in the standard ČSN 75 7221, which concerns the classification of surface water quality [16] and ČSN 75 7143 - water for irrigation [7].

5. Conclusion

The research studies are aimed at refuting the negative view and suggest the use of treated wastewater for large-scale emergencies, especially industrial or agricultural facilities, where the use of drinking water from the hydrant network can solve the supply of fire water to the population in times of crisis. Chemical and biological analyzes have dispelled possible unfounded concerns about the use of this water. The WWTP is an ideal place for the establishment of pumping stations for fire brigades and also an optimal base for the distribution of fire water to the burning site with secured occipe and technical equipment. From the point of view of fire technology, there are no obstacles to pumping this water. It is clearly recommended to use purified water from the WWTP. Especially for regions that regularly suffer from water shortages due to long-term drought, WWTPs are a optional source of fire water (forest fire fighting).

The aim is to draw attention to the hidden potential of this alternative and underused water source in the form of a WWTP. The tests performed were at the regional level at one WWTP. For deeper implementation of the use of this resource, it is necessary to carry out further testing at the national level. Equally important is the legislative enshrinement of the use of purified water from the WWTP. Signing up for one of the environmental statements, either in the ISO14001 or EMAS concept, would be completely positive on the part of the management of the Fire and Rescue Service of the Czech Republic.

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