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ASSESSMENT OF THE INFLUENCE OF MINE WATERS ON SURFACE WATER QUALITY IN OSTRAVA-KARVINA REGION

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ABSTRACT

The study deals with the evaluation of the effects of mining water on surface water quality in the Ostrava-Karvina region. The rivers were monitored from March 2019 to February 2021 and results were evaluated according to Government Regulation No. 401/2015 Coll. Mine waters are primarily loaded with dissolved substances, namely chlorides. Among others, the study focuses on parameters like temperature, pH, conductivity, sulphates, suspended solids, iron, manganese and radioactivity. The influence of mine water outlets was proven in the study, namely the influence of Jeremenko Water Pit on the monitored area of Ostravice River and the influence of Karvinský Potok tributary on the monitored area of Olše River. The Orlovská stružka did not have such a demonstrable effect on the monitored area of Odra River as the aforementioned outlets on other rivers.

Keywords: Influence of mine waters; Karvinský potok; Mine waters; Orlovská stružka; Water Pit Jeremenko.

1 INTRODUCTION

Coal mining, as well as the mine waters associated with it, affects the environment. There are changes in both the biotic and abiotic components of the environment. The composition and amount of mine waters affects the quantity of changes in biotic and abiotic components of the environment.

The term “mine water” is defined by Act no. 44/1988 Coll., on the protection and utilization of mineral resources (Mining Act) [1]. It was later amended to the current Act No. 451/2016 Coll. as amended [2]. Mine waters are “*all underground, surface and rainwater*” that have entered, regardless of the method, “*by percolation or gravitation from the overburden, subsoil or flank or by simple inflow of rainwater until they join other permanent surface waters or underground waters*” into the mine premises. Mining areas are all mine works that are mined, buried or founded, located in underground mines, areas after the extraction of a deposit in a quarry, clay pit or after the extraction of gravel and sand from water, including deposits of mineral resources that are mined below the water level, in alluvial floodplains or from the bottom of the water recipient.

The composition of mine water is mainly influenced by the mined raw material. Mine water which comes from underground coal mining is characterized by a high content of dissolved substances (salinity caused by chlorides) and a higher content of sulphates. Their concentration is mainly influenced by the amount of sulphides (mainly pyrite), which are present both in the coal component and also in the tailings. Acid Mine Drainage (AMD) is created by the weathering of sulphides [3][4][5]. It can be formed in parts (groundwater) of underground mines. But this has a little of importance if the mine is in active production and water levels are kept artificially low by pumping. However, if the mines are closed and abandoned and the water is not pumped, the increase in the water level can lead to the penetration of contaminated groundwater into the environment [4].

It should be noted that both the quality and quantity of mine water during the period of active underground mining differ significantly from the state after its termination, however, their classification remains the same. Mine water can basically be considered as mainly mixed water, or water that has changed chemism. Mine water is created by a mixture of different proportions of both natural and anthropogenic sources, it is part of the mined raw material, or it is only a transport medium [6]. The ratio and representation of individual physical and chemical parameters affecting the water quality in mine waters can be the result of a whole range of different factors (e.g., the intensity of mining, amount of extraction works, the position of mine in relation to the main aquifer horizons of the area, etc.). With the advancement of the mine to depth, and also in connection with the distribution of mining and the opening of individual parts of the mining area, not only the quality but also the quantity of mine water changes [4][7][8][9].

The natural source of groundwater in the Czech part of the Upper Silesian Basin is the water of the Quaternary aquifers and the water of the aquifers of the Carboniferous Lower-Baden cover. Groundwater basically comes from the upper aquifer sandy pelitic complex facies. Another source can also be gravelly and sandy basal clastics of the lower Baden (detrital horizon). The most common type of water of a detrital aquifer is water that is highly mineralized (20–35 g l^{-1}), with relatively simple chemism. It is water of the sodium-chloride type (Na–Cl), i.e., fossil synsedimentary groundwater [6][10]. The aim of the study was to determine whether mine waters in selected locations have an effect on surface waters.

2 METHODOLOGY

The Ostravice, Olše and Odra rivers were monitored from March 2019 to February 2021. Sampling within individual sites (Table 1) took place in the upper part of the stream (marked A), the outlet of mine water into the stream (marked B) and the lower section of the stream at a distance of approximately 500 m from the outlet of mine water (marked C). The water samples from the upper sections of streams were used to determine the hydrochemical parameters before the outlet of mine waters into the recipient.

Table 1. *GPS coordinates of water samplings of Ostravice, Olše and Odra rivers*

Sample identification	Sampling point	N	E
1 A	Ostravice upper stream	49°48’7.829”	18°16’54.053”
1 B	Water pit Jeremenko	49°48’11.817”	18°16’56.502”
1 C	Ostravice lower stream	49°48’14.834”	18°16’59.731”
2 A	Olše upper stream	49°53’12.167”	18°29’11.014”
2 B	Karvinský potok	49°53’15.053”	18°29’12.519”
2 C	Olše lower stream	49°53’17.815”	18°29’13.871”
3 A	Odra upper stream	49°53’46.165”	18°19’05.683”
3 B	Orlovská stružka	49°48’7.829”	18°16’54.053”
3 C	Odra lower stream	49°48’11.817”	18°16’56.502”

Samplings for the laboratory part of the analysis, meeting the standard ČSN EN ISO 5667-6 [11], were sent to the Nanotechnology Centre VŠB-TUO laboratory, for metal determination. Those samplings were conserved.

Radioactivity (alpha and beta, Radon, Radium 226, Radium 228 and Lead 210 isotopes) was determined in laboratories of Główny Instytut Górnictwa, Katowice, Poland. In the laboratories of VŠB-TUO, specifically the Department of Environmental Engineering (KEI), chlorides, sulphates, and suspended solids were determined. All parameters were determined according to relevant standards verified in laboratories.

Monitoring and analysis of results took place within the framework of the Czech-Polish SUWAT project no. CZ.11.4.120/0.0/0.0/17_028/0001633[12]. The project was conducted as a cross-border collaboration between VŠB – Technical University of Ostrava and Główny Instytut Górnictwa, Katowice. The project ran from February 2019 to April 2021 (SUWAT, 2021).

The **temperature** (with an accuracy of ± 0.1 °C)**, conductivity** and potential of hydrogen (**pH**) were measured by the terrain apparatus MP–6 HACH (fa, HACH Germany).

Sulphates were determined by the spectrophotometric method with the HACH DR 2800 (fa HACH, Germany). Method 10248, SulfaVer 4 Method Powder Pillows, was used. The principle of the method is the reaction of sulphate anions with barium in the sulphate reagent SulfaVer 4 to form faintly soluble barium sulphate. The amount of precipitate is directly proportional to the sulphate concentration. The measurement uncertainty is 10 %.

Chlorides were determined according to the applicable standard ČSN ISO 9297 (75 7420) Water quality. Determination of chlorides. Silver nitrate titration with chromate indicator (Mohr's method) [13]. At the equivalence point, a brownish-red precipitate of silver chromate (Ag_2CrO_4) is formed. For better precipitation, it is recommended to maintain the pH value during the titration in the range of 5.0–9.5. Considering the pH value of the samples taken, there was no need to adjust the pH value. Measurement uncertainty is 9 %.

Suspended solids (SS_{105}) were determined according to the standard ČSN EN 872 (757349). Water quality – Determination of suspended solids – Method by filtration through glass fibre filters [14].

Each hydrochemical parameter was measured three times and the presented results are the average values of these measurements. The results of the study, including statistical parameters, were evaluated in Microsoft Office Excel 2007 and Microsoft Office Excel 2016.

The results were subsequently compared with limit values of the Government Regulation No. 401/2015 Coll., on indicators and values of permissible pollution of surface water and wastewater, requirements for permits to release wastewater into surface waters and into sewers and about sensitive areas and surface waters [15].

3 RESULTS AND DISCUSSION

Considering the theoretical assumptions, one may expect an increase in the values of dissolved substances, chloride and sulphate ions, conductivity and temperature. It was proved from results that the Water Pit Jeremenko (1B) significantly increases water temperature, but only in the immediate vicinity of the outlet from the mine water (1B) to the Ostravice River (1C). The temperature in the lower stream of the Ostravice River (1C) increased by an average 5 °C due to mine water, which may affect organisms that are not adapted to higher temperature conditions. The temperature may also affect the effectiveness of self-cleaning mechanisms, which can be slowed down due to higher temperature. This may have a significant effect on the quality of water in the immediate vicinity from the outlet of mine water to the rivers. Significant thermal pollution, mainly in the warmer summer months, can cause a major oxygen deficit even without the presence of other pollutants and affect the life in the stream. This tends to be a serious problem, especially in small watercourses.

Increased concentrations of **chlorides** in the water system may harm aquatic organisms and disrupt osmoregulation. Osmoregulation helps to maintain the correct concentration of chlorides. The highest measured value of chlorides was observed at the mine water outlet from the Water Pit Jeremenko (1B) and subsequently at the lower stream of the Ostravice River (1C), as well as at the mine water outlet from the Karvinský Potok (2B) and subsequently in the lower stream of Olše River (2C). The influence of the Orlovská stružka (3B) on the lower stream of Odra River (3C) was not as significant as it was at the above-mentioned rivers. This may be caused due to the dilution of the mine water in the recipient due to the longer distance from the mining water outlet (3B) to the lower stream (3C). Even though the increase and influence of the mining water on immediate vicinity of the Orlovská stružka outlet (3B) on the lower stream of Olše River (3C) was also evident.

Another monitored parameter in individual streams was **manganese.** Based on the obtained results, it can be stated that the average annual permissible manganese pollution ($0.3\ mg \cdot l^{-1}$), specified by Government Regulation No. 401/2015 Coll., [15] was not exceeded in any of the monitored streams. It can therefore be concluded that this hydrochemical parameter does not represent a risk for surface water quality in the evaluated area.

In addition to manganese, the development and influence of **iron** in individual streams was also monitored. According to Government Regulation No. 401/2015 Coll., [15] the average annual permissible pollution of iron ($3\ mg \cdot l^{-1}$) was not exceeded at any of monitored areas. Even iron does not represent a risk for surface water quality at any of the monitored streams.

The development of **pH** in individual streams was also monitored. According to Government Regulation No. 401/2015 Coll. [15]. The average annual range of pH values (6–9) was not exceeded at any of the locations. In the first monitored period (2019/2020), the average annual pH value in the upper stream of Ostravice River (1A) was

9. In the lower stream of Ostravice River (1C), the average annual pH value was 8. It was proven that mining waters, the average annual pH value of which was 7, had effect on the reduction of the pH value in the streams, for all monitored rivers.

Suspended solids in individual streams were monitored according to Government Regulation No. 401/2015 Coll. [15] Average annual permissible pollution (20 $mg \cdot l^{-1}$) was exceeded only in the first measured period at the location of the lower stream of Olše River (2C), as well as at the Orlovská stružka outlet (3B) and the lower stream (3C) of Odra River. While in Odra River was proven influence of mining water on the surface water, in Olše River it was probably only the influence of precipitation on the value of suspended solids.

The content of suspended solids depends on many circumstances, both natural and anthropogenic. In the case of the Karvinský potok (2B) and the Olše River (2) in the first measured period (2019/2020), the increase in suspended solids is most likely caused by the amount of precipitation in the sampling days and the fact that the sampling point is located right behind the Dětmarovický Jez (Dětmarovice Weir), which may also be a possible cause of increase in suspended solids in Olše River. The highest average annual concentration of suspended solids in Olše River was measured on the lower stream (2C). This increase is not attributed to the influence of mine water, but to the location and rainfall. In the second monitored period (2020/2021), the value of suspended solids were significantly lower. However, in the first monitored period, above-limit values also appeared in Odra River, where the influence of mine water on Odra River can be assumed, because the lowest concentration of suspended solids was found at the sampling point (3A) and the highest at the sampling point (3B). In the second monitored period, however, the limit was no longer exceeded, but a certain influence of suspended solids on the Odra River was still observable.

The last monitored parameter was **radioactivity**. According to Government Regulation No. 401/2015 Coll. [15], the maximum permissible pollution value of total volume activity α is in concentrations of 0.3 $Bq \cdot l^{-1}$ and the annual average pollution is permissible in concentrations of 0.2 $Bq \cdot l^{-1}$. The total volumetric activity β, is permissible at maximum concentrations of 1 $Bq \cdot l^{-1}$ and its annual average of permissible pollution is 0.5 $Bq \cdot l^{-1}$. The maximum concentration of Ra^{226} is permissible up to a maximum concentration of 0.5 $Bq \cdot l^{-1}$. The annual average of total volume activity α and total volume activity β did not exceed the maximum permissible concentration at any of the monitored locations. It can be stated that the surface water of the monitored streams is not contaminated with radioactive elements, of which the source could be the mine waters outlet.

4 CONCLUSION

Based on the two-year period of monitoring and its subsequent evaluation, it was found that the most important influence out of all three sites had the Water Pit Jeremenko on the Ostravice River, in the immediate vicinity of the outlet from the mine water, while the Orlovská stružka had the least influence on the Odra River.

Chlorides were the most significant contaminating parameter. They affected the Ostravice, Olše and Odra rivers. For this parameter, the influence of mine waters on surface waters was proven. The biggest increase in chlorides was detected in the Ostravice and Olše rivers. Significant influence of mine waters was also demonstrated on the Ostravice and Olše rivers in terms of **dissolved substances**. In both monitored years the values exceeded the limits stipulated in Government Regulation No. 401/2015 Coll. Another parameter that was significantly increased was conductivity, which considering the composition of mine water in Ostrava-Karviná Region, correlates with results of chlorides. The mine water outlet from the Water Pit Jeremenko had an effect on the temperature in Ostravice River. In the case of the Karvinský potok and Olše River in the first period (2019/2020), an increase in suspended solids was detected, but this was demonstrably unrelated to mine water. Most likely, this increase was caused by the rainfall on the sampling days and the fact that the sampling point is located right behind the Dětmarovický Jez (Dětmarovice Weir). In the second monitored period, the values of suspended solids were already within the limit and significantly lower.

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