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THREATS OF HIGHLY ALKALINE WASTEWATER DISCHARGE TO SURFACE WATER

ODPROWADZANIE WYSOKO ALKALICZNYCH ŚCIEKÓW DO WÓD POWIERZCHNIOWYCH

Abstract

The paper discusses the discharge of highly concentrated alkaline wastewater from an industrial reservoir and its effect on surface waters. The discharge source is the Górka industrial reservoir, located in Trzebinia. The wastewater constitutes a threat to groundwater, which serves as a source of drinking water for surrounding villages. A detailed analysis of pH confirmed a high alkalinity of the tank content; the pH values were in the range of 12.5 to 13.5. Other water quality parameters (COD, sulfates, chlorides, TSS) were also very high. Initially, wastewater was discharged to the wastewater treatment plant (WWTP) in Chrzanów. Then, since the plant had refused further treatment due to operational disturbances, wastewater had to be discharged directly to the Chechło and Ropa creeks and finally to the Vistula river. A simultaneous monitoring of the water quality in these streams was provided. Wastewater discharged from the Górka reservoir was gradually diluted on its way to the Vistula river and therefore its impact on the Vistula river has been insignificant. The method turned out to be both effective and safe for the aquatic environment.

Keywords: *alkaline wastewater*, *groundwater quality protection*, *surface water quality*

Streszczenie

Artykuł przedstawia zagadnienie odprowadzania silnie stężonych ścieków alkalicznych ze zbiornika poprzemysłowego Górka w Trzebini do wód powierzchniowych. Ścieki te stanowiły zagrożenie dla wód podziemnych zaopatrujących w wodę okoliczne miejscowości. Szczegółowa analiza odczynu pH wskazywała na wysoką alkaliczność cieczy w zbiorniku, wartości wahały się w granicach 12,5–13,5 pH. Pozostałe wskaźniki jakości wody (ChZT, siarczany, chlorki, zawiesina) również były bardzo wysokie. Ścieki te początkowo były odprowadzane do grupowej oczyszczalni w Chrzanowie Ze względów eksploatacyjnych oczyszczalnia odmówiła dalszego przyjmowania ścieków, co spowodowało konieczność odprowadzania ścieków ze zbiornika bezpośrednio do wód powierzchniowych potoków Ropa Chechło, a w konsekwencji do Wisły wraz z jednoczesnym monitorowaniem stanu jakości wody w tych potokach. Na każdym etapie przepływu ścieki odprowadzane z Górki ulegały rozcieńczeniu. Rozcieńczenia spowodowały znaczny spadek stężeń w odbiornikach. Wpływ odprowadzanych ścieków na rzekę Wisłę jest nieznaczny. Zastosowana metoda okazała się skuteczną i bezpieczną dla środowiska wodnego.

Słowa kluczowe: *ścieki alkaliczne*, *ochrona jakości wód podziemnych*, *jakość wód powierzchniowych*

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1. Introduction

The Górka reservoir is located in the city of Trzebinia. During industrial activities of the former Górka cement plant, marl, for cement production, was excavated from the Górka quarry. In the years 1962–1984, solid waste from the production of aluminum hydroxide from bauxite processing was stored in the existing excavation pit. The excavation pit holds about 400,000 tons of waste; the thickness of the waste layer is 16–18 m while its overall area covers approximately 2.5 acres. The excavation pit also stored other waste materials such as chamotte rubble, slag, ash and others. The total amount of stored waste (red mud type) was around 600 thousand m^3, i.e. approximately one million tons. The excavation pit and landfill areas occupy 24.3 acres in total, from which 16.8 acres is reserved for a landfill while the remaining 7.5 acres is a pond [1, 2].

A geological structure around the excavation pit is unfavorable from the perspective of environmental hazards. Jurassic and Triassic formations house the underground water reservoirs, which are very susceptible to penetration and the spread of contaminants. The landfill is located within the recharging zone of these reservoirs, which are also located in the excavation pits of the Trzebionka zinc and lead mine. Groundwater from these excavations supplies the municipal water system in Trzebinia. The uncontrolled intrusion of polluted water into the mine may cause the irreversible contamination of groundwater; additionally, it makes possible hydraulic contact with the underground reservoir GZWP no. 452. The reservoir serves as the main water supply source not only for the Trzebinia residents, but also for the whole of Chrzanów County [3].

2. Methods

By 1991 the wastewater was occasionally pumped out into the sewer and then transferred to the Chrzanów. In 1991, the discharge from the reservoir was brought to an end and a surge of water was observed. Water table elevations rose steadily and eventually a pond was created, where approximately 400,000 m^3 of contaminated water was retained. In 1992, the pumping of wastewater out of the reservoir to the Chrzanów WWTP was resumed. Such actions lasted intermittently until 1997 when it was discontinued due to the treatment plant failing to meet the water permit conditions [3].

In 2000, due to the uncontrolled discharge from the reservoir, the concept of pumping out the wastewater from the reservoir to the surface water came up. Such an approach enabled the satisfactory protection of the reservoir bed and withhold the discharge flow to the excavation pits and groundwater. In the same year, a water permit was granted for wastewater discharge. However, there was still no proper installation to perform such actions and the wastewater kept overflowing into surface waters. In 2005, a lowering of the liquid level was initiated by pumping and discharge of wastewater through a tunnel to a creek flowing out of the Balaton quarry and then to the Ropa and Chechło creeks. The liquid was pumped out with a set of floating pumps with a capacity of 8.1 dm^3/s; the pumps were resistant to alkaline compounds. The draining off of the reservoir, initiated in 2005, proceeded in several stages and eventually a liquid level in the reservoir was over 10 m lower. Wastewater drained from the tank was transported via a 160 mm pipe diameter directly to the Ropa creek.

In the years 2005–2008, the draining of the reservoir was continued and wastewater was pumped out and discharged to the Ropa creek. Currently, the reservoir holds 20,000 m^3 to 23,000 m^3 of wastewater; about 15,000 m^3 saturates a solid waste dump while the remaining 8,000 m^3 fills the cavities in the bottom of the reservoir [4].

Table 1 presents data relating to the water quality in the reservoir. The parameters show a systematic increase along the reservoir's depth (13 m); particularly hazardous for the aquatic environment are high values of pH and alkalinity. Additionally, other parameters significantly exceed the values specified in the Regulation of the Minister of Environment dated July 24, 2006 on the conditions to be met when discharging sewage into water or soil, and on substances particularly harmful to the aquatic environment [4].

Table 1

The Górka reservoir water quality [1]

Parameter	Unit	Range, min.–max.
pH	–	11.7–13.3
Alkalinity	mval/dm^3	97–304
COD	mg/dm^3	177–1,311
Specific conductivity	mS/cm	5,000–71,130
Sulfates	mg/dm^3	500–2,300
TDS	mg/dm^3	7,628–38,966
Lead	mg/dm^3	0.006–0.0166
Aluminum	mg/dm^3	25.2–206.7
TSS	mg/dm^3	10–538

3. Wastewater discharge from the Górka reservoir

Wastewater from the Górka reservoir, having passed through a tunnel and pipes laid in trenches A and A-1, are discharged to the Ropa creek and the Chechło river; their final destination is the Vistula river.

Trench A drains excess water from the Balaton reservoir ('class I' water quality, used for recreation). Here, the contaminated wastewater from the Górka reservoir becomes for the first time substantially diluted with water from the Balaton reservoir. A subsequent dilution takes place in ditch A-1, which receives both water from a storm water drainage system from the Metallurgy Plant in Trzebinia and excess water from the Balaton reservoir. Wastewater then enters the Ropa creek. The Ropa creek receives water from the areas located between the Chechło river (from the south) and the industrial premises (to the north). Its water, though diluted with water from the Balaton reservoir and pre-treated wastewater from the EkoNaft Refinery in Trzebinia, is already polluted. The pollutant load is mixed with a diluted stream from the Górka reservoir.

The Ropa creek enters the Chechło river, which is a left-bank tributary of the Vistula river. The Chechło river, which is also a recipient of the Chrzanów WWTP effluent and waters

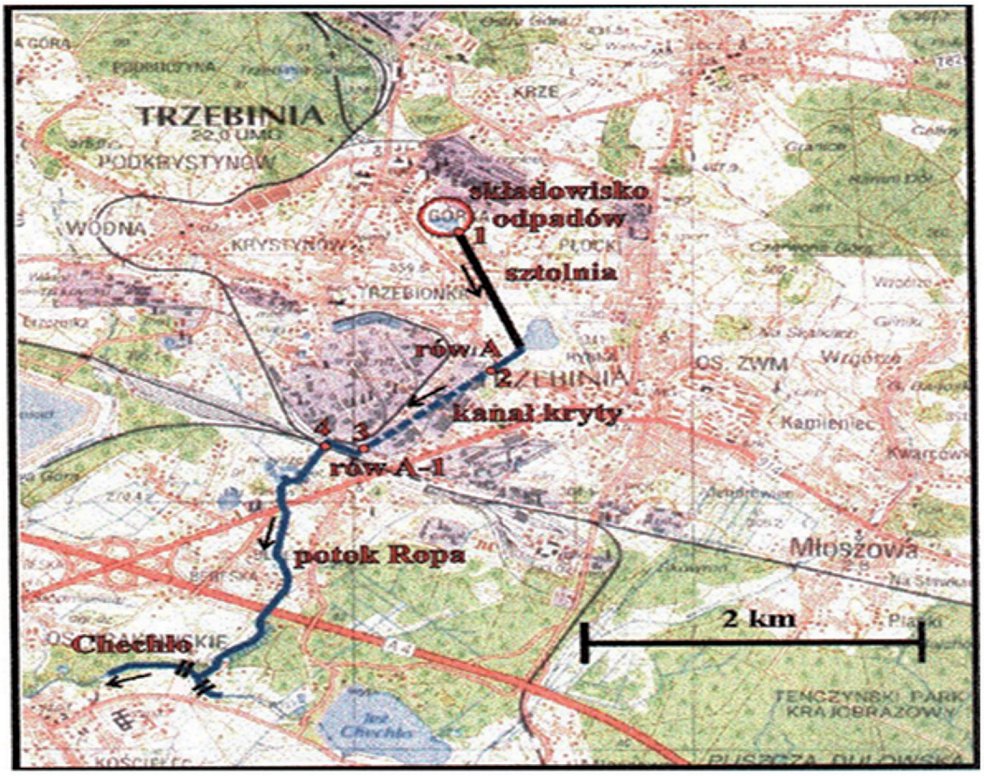

Fig. 1. Discharge of wastewater from the Górka reservoir: 1 – drill hole, 2 – manhole at the inlet to a tunnel, 3 – tunnel outlet, 4 – culvert under a railway embankment [1]

from catchment areas, once again dilutes water from the Górka reservoir by mixing it with other surface waters. The Vistula river is the final destination of all water streams; its flow is so large, compared to the Chechło river, that it dilutes the incoming waters.

4. Quality of a discharged wastewater

Water quality in creeks was monitored to determine how the reservoir discharge affects their water quality. The following parameters were analyzed: pH, alkalinity, total suspended solids (TSS), COD, sulfate and chloride [5]. The discussion was based on changes of pH shown in the graphs (Figs. 2–4). They present the pH changes taking place along the Ropa and Chechło creeks in the years 2006–2008. In 2006, the average pH level was maintained at 8–8.4 at all measurement points (Fig. 2). At the end of the year (October–December) a drop of pH down to 7.1–7.8 was observed in the Ropa creek (first measurement point, upstream from the Oil Refinery WWTP); the pH values again reached a level of 8–8.3 in mid-December.

Such a decrease may be caused by a higher water inflow from the areas adjacent to the Ropa creek due to the torrential rains that occurred at that time. Downstream from the Oil Refinery WWTP, the pH level in the Ropa creek resumes the value of 8–8.4, probably due to wastewater discharged from the Chrzanów WWTP. In 2007 (January–March), the pH level increased to over 13 at the first measuring point (Fig. 3) while at the remaining points,

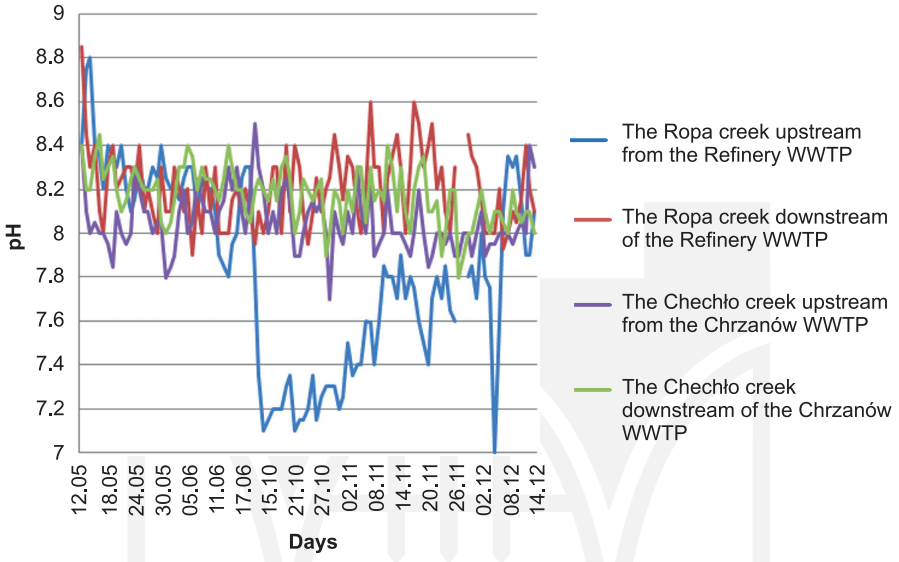

Fig. 2. pH changes along the discharge from the Górka reservoir in 2006

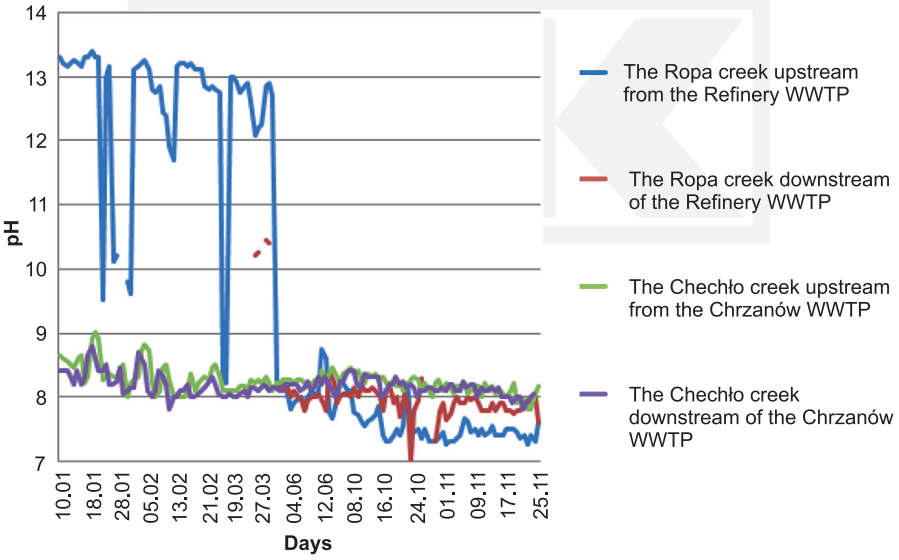

Fig. 3. pH changes along the discharge from the Górka reservoir in 2007

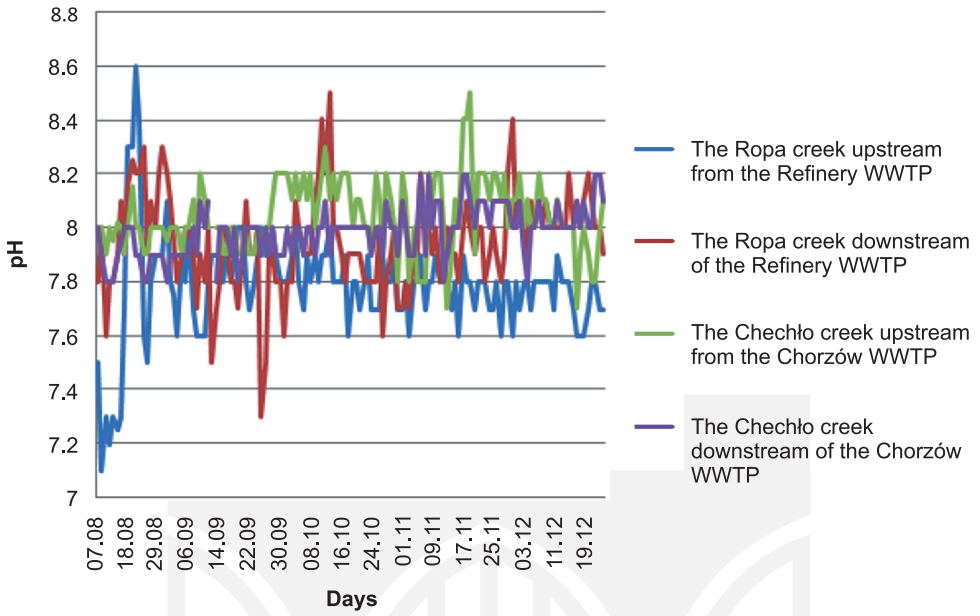

Fig. 4. pH changes along the discharge from the Górka reservoir in 2008

it maintained the level of 8–8.4. This increase may be attributed to the fact that the liquid pumped out from the Górka reservoir was discharged to the Ropa creek at that time. Once the pumping stopped, pH values returned to their previous levels. However, in 2008 (Fig. 4), the pH value remained rather stable within the range of 7.6–8.6 with no significant changes observed.

Except for an increase of pH in early 2007, pH values have remained stable and do not pose any hazards to the biological life in rivers.

5. Impact of Górka's reservoir discharge on water quality

The impact of wastewater from the Górka reservoir was determined by calculating the pollution increase Δs in the creeks' water, according to the formula:

$$\Delta s = S_e \times Q_{śc} / (SNQ + Q_{śc})$$

where:

SNQ – reliable flow in a creek [dm^3/s],
$Q_{śc}$ – wastewater flow from the reservoir, $Q_{śc}$ = 8.1 dm^3/s,
S_e – average concentration in wastewater from the Górka reservoir [mg/dm^3].

The results are shown in Tab. 2, while Tab. 3 presents the actual concentrations of pollutants in creeks' water at the time of wastewater discharge from the Górka reservoir.

Table 2

Increase of concentrations in receiving water due to the Górka reservoir discharge

Creek/river	$Q_{ść}$ /SNQ [dm³/s]	COD [mg/dm³]	Chlorides [mg/dm³]	Sulfates [mg/dm³]	TSS [mg/dm³]
Górka	8.1	707	397	1,803	57
Ropa	10.8	303	170	773	24
Chechło upstream from the WWTP	350	16	9	41.5	1.3
Chechło downstream from the WWTP	640	9	5	23	0.7

The calculated changes in concentrations in the various streams indicate a gradual dilution of the Górka discharge in following receiving water bodies.

Table 3 presents the average values of parameters in the creeks/rivers in 2006–2007 and compares them to the limits set for the water of class II (Annex 5, Regulation of the Minister of the Environment, issued on November 9, 2011) [6].

Table 3

Average concentrations of pollutants in creeks/rivers during wastewater discharge from the Górka reservoir

Creek/river	COD [mg/dm³]	Chlorides [mg/dm³]	Sulfates [mg/dm³]	TSS [mg/dm³]
Górka	707	397	1,803	57
Ropa	116	63	128	13
Chechło upstream from the WWTP	24	75	491	10
Chechło downstream from the WWTP	34	86	481	13.6
Limiting values as in [6]	30	300	250	50

Environmental objective of the water segment defined as "the segment of the Chechło creek measured from the Ropa creek down to the Chechło's creek mouth" assumes a good water status.

As shown in Tab. 3, the water quality standards for class II (Annex 5, Regulation of the Minister of the Environment [6]) were exceeded only for sulphates and the Górka's reservoir discharge had little effect on the increase of this parameter (see Tab. 2). Higher concentrations of sulphates observed in the Chechło creek were caused by pre-treated wastewater, discharged from the Eco-Naft WWTP. Elevated values of the other parameters in the Chechło creek may be attributed to effluent discharges from the Chrzanów WWTP.

6. Conclusions

- The Górka reservoir, filled with strongly mineralized water with a high content of organic compounds and metals, was a major threat to the environment. Permeation of the liquid into groundwater threatened contamination of water resources used for municipal purposes. It was necessary to empty the tank and clean up waste lying at its bottom as soon as possible.
- The proposed solution assumed the discharge of wastewater from the reservoir by periodic pumping and transfer to surface waters in a controlled manner; such an option seems to be acceptable with no negative impact on water quality.
- After the Górka reservoir's discharge, the limiting values for the class II of water [6] were exceeded only for sulphates (Chechło creek, upstream from the Chrzanów WWTP). The increase was not caused by a wastewater discharge from the Górka reservoir.
- Discharge of wastewater from the Górka reservoir enables further comprehensive reclamation of lands degraded by industry.

References

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