

WATER QUALITY OF THE DOA STREAM IN GLIWICE (SOUTHERN POLAND) IN THE CONTEXT OF THE FUNCTIONING OF THE NEW DRY RETENTION RESERVOIR

Marek Ruman, Paulina Kowalczyk, Dominika Dąbrowska, Wojciech Rykała

University of Silesia in Katowice, Faculty of Natural Sciences, 60 Będzińska Street, Sosnowiec, Poland

ABSTRACT

Maintaining the appropriate quality of surface waters in urban areas is one of the significant environmental problems. Failure to monitor the chemical and quantitative status and control industrial facilities may lead to environmental and human health hazards. The Doa stream catchment area is one of the last natural areas in Gliwice (southern Poland), which makes it the subject of a conflict between the need to build flood protection infrastructure and environmental protection. During the annual studies of changes in the quality of surface waters in the Doa stream, a clear seasonality of physicochemical parameters was observed, resulting from both natural annual cycles and anthropogenic impacts. The calculated Nemerow indices reach almost 18 in the spring months and about 25 in the winter months, which classifies the water quality in this stream as the V quality level. Additionally, the differences between the electrical conductivity value at individual measurement points indicate a deterioration in the quality of the stream after flowing through the retention reservoir. For this area, a detailed environmental inventory of the catchment area, regular monitoring of the reservoir's effectiveness in terms of reducing flood risk and improving rainwater retention, and an assessment of whether the reservoir causes any negative impact on local ecosystems, particularly in the context of hydrological changes, water quality and biodiversity, are suggested.

Keywords: water quality, pollutants, Nemerow Index, Doa stream.

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INTRODUCTION

Nowadays, rapid urbanization and intensive urban development generate numerous challenges related to environmental protection, water resources management and maintaining biodiversity. A growing number of terrestrial and aquatic ecosystems are being impacted by drought and flooding, which are changing entire regions due to continuous climate change [1]. Climate change has an impact on water quality and hydrologic conditions due to the drying out of aquatic ecosystems. Drought impacts global hydrology and water quality as a result of atmospheric warming and precipitation changes, posing a significant threat to the supply of water for ecosystems and citizens [2]. Through pollution and changes in hydrological components, this also affects water balance and quality throughout land regions worldwide, endangering ecosystems' water supplies [3]. The expansion of urban areas increases the area of sealed catchments, while reducing biologically active areas [4]. Long-term and constant lack of water or its excess weakens the natural defense mechanisms of many organisms [5]. This increases their susceptibility to diseases. During periods of drought, herbaceous vegetation of most species dries up, which causes the depletion of the food base of other organisms. During floods, putrefactive conditions occur and vegetation is destroyed. The living and reproductive conditions of many water-related species deteriorate, which consequently leads to their extinction [6].

In this context, retention reservoirs play a key role in managing stormwater, preventing urban floods and ensuring water availability during periods of deficit. Retention reservoirs in cities not only serve as storage for excess stormwater, but can also be used as a recreational, flood-fighting and natural element in the urban structure [7, 8]. Additionally, small water are utilized for tourism activities such as swimming, water sports, and fishing. When constructing water reservoirs, it is important to consider both the amount and quality of water that will be retained. Pollutants that flow into the reservoir, mostly in the form of water and river load, might frequently endanger its existence and utilization [9, 10]. Properly designed reservoirs contribute to improving the microclimate by lowering temperatures in hot months and supporting the development of green spaces. Their role is not limited to the technical function of storing water, but

also has a broad significance for improving the quality of life of city dwellers [11].

At the same time, ecological corridors, such as river valleys connecting isolated fragments of ecosystems, have become a key tool in the last decades in preserving biodiversity and enabling the movement of species in highly urbanized areas [12]. Intensive development of infrastructure, development of green areas and increasing fragmentation of natural habitats lead to the degradation of ecosystems and the isolation of species. Ecological corridors enable the migration of animals, the spread of plants, and the preservation of natural ecological processes in cities [13].

Both retention reservoirs and ecological corridors are becoming an inseparable element of contemporary sustainable urban planning. In an era of climate change, when cities must face both growing water threats and the need to preserve natural resources, these structures play an invaluable role in shaping spaces that are not only functional, but also environmentally and resident-friendly [14].

The aim of the article is to determine the quality of surface waters in the Doa Stream in Gliwice (southern Poland) in the context of assessing the functioning of a new dry retention reservoir. This reservoir was built due to the need to prevent flooding of lower-lying areas of the city. Due to the planned location of the reservoir in the ecological corridor zone, its construction aroused controversy on the part of the local community. The reservoir was put into service in 2023, leaving its basic function, i.e. flood protection, taking into account some of the society's demands, also giving it a recreational and natural character.

STUDY AREA

The analyzed study area includes the Doa stream catchment located in Gliwice (southern Poland, Fig. 1). According to the division of Poland into physical-geographic regions according to Kondracki [15], Gliwice is located in the Silesian-Cracow Upland subprovince, which includes the Silesian Upland macroregion and the Katowice Upland mesoregion.

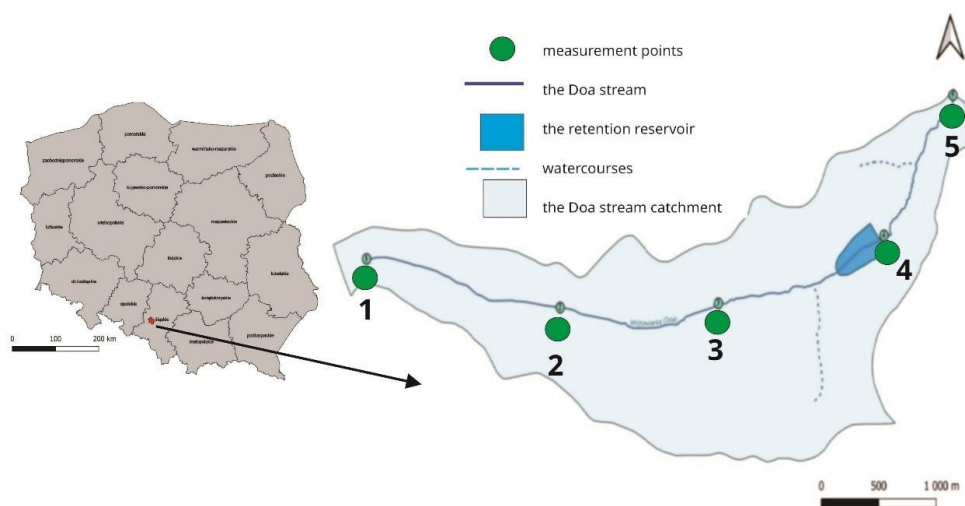


Fig. 1 Study area.

According to the regionalization of the climate of Poland by E. Romer [16], Gliwice is located within the range of the climate of the central uplands (Silesian-Cracow region). The most numerous air masses are of polar-maritime origin (65%) as well as polar-continental air (20%). The least common air masses inflowing to the Gliwice area are tropical-maritime and tropical-continental air (6-8%). Air masses flowing from the Atlantic Ocean have a decisive influence on the formation of climatic relations in the studied area, which is why westerly winds dominate there, constituting 46.6% of all studied cases. In the period 1961-1990 in Gliwice the average annual precipitation was 655 mm. The average annual air temperature in the studied area is 7-8°C. The month with the lowest average temperatures is January, with values around -3°C, while the warmest month is July with average temperatures of 18.0°C [17]. In terms of geology, the analyzed study area is located within the Upper Silesian Depression, which is part of the Silesian-Cracow Upland. The geological profile includes Carboniferous, Triassic, Tertiary and Quaternary formations [18]. The Triassic rock formations, which form a continuous cover of 50-60 m in thickness, are represented by sediments from the Lower Triassic and Middle Triassic – Muschelkalk. In the discussed area, rock formations such as clays, marls, limestones, salts, sands and gravels are classified as Tertiary formations, which come from the Upper Miocene. Quaternary formations, which include sands, gravels and in places clays, reach a thickness of 50-60 m, forming a discontinuous cover.

The entire area of the city belongs to the Odra River basin, it consists of right-bank tributaries and their basins, and the direction of surface water runoff is generally west and north-west. The streams mostly run latitudinally, from east to west. The hydrographic network consists mainly of lowland permanent streams, with a slight slope and low erosion force, and in highly degraded areas and in the upper sections, the streams are of a seasonal nature. This, which ultimately causes the culmination of runoff in such strongly transformed catchments to occur in any month of the hydrological year [19]. The main river flowing through Gliwice is the 75.3 km long Kłodnica, which is also a right-bank tributary of the Odra. In Gliwice there are many water reservoirs of anthropogenic origin, formed in the Kłodnica valley as

a result of blocked water outflows, in sand mining excavations, and in subsidence basins. In the analyzed study area, in terms of hydrogeology, there are aquifers within Pleistocene and Miocene sediments, while the most important are the Muschelkalk and Rött aquifers associated with limestones and dolomites. These two levels are locally in hydraulic contact.

The Doa stream is located in the southwestern part of the city of Gliwice. Another name for this stream is Wójtowianka. It is a right tributary of the Ostropka (a III-level watercourse). The length of the stream is about 6.12 km, the catchment area is about 6.08 km², and the catchment area is 14.52 km². The source of the stream is located at an altitude of 270.05 m above sea level in the Ostropa district. The catchment denivelation, defining the difference in height between the highest and lowest point within the catchment, is 51.94 m. The average height of the catchment reaches 244.08 m, and the slope of the catchment area is 21.06 ‰. The slope of the watershed, which is the slope of the catchment boundary, is 3.58 ‰. The Doa Stream catchment area is part of the Surface Water Body called "Kłodnica from Promna to the Dzierżno Duże reservoir" (<http://karty.apgw.gov.pl/>).

The first mentions of the construction of a retention reservoir on the Doa stream come from 2009 in the hydrological documentation developed by the Multi-Branch Company "EnEko" at the request of the City Office in Gliwice. In 2012, the GIG Katowice - Water Protection Plant prepared an expert opinion on possible hydrotechnical operations aimed at protecting areas located on the border areas of the Gierałtów Commune and the City of Zabrze against flooding, as well as further along the Kłodnica River in the City of Gliwice. The Water Projects Office, Land Reclamation and Environmental Engineering "BIPROWODMEL" from Poznań, at the request of the City Office in Gliwice, in 2016 prepared a document entitled "Dry retention reservoir on the Wójtowianka stream (Doa), construction design, architectural and construction design", which presented the characteristics of the planned investment area together with photographic documentation of the stream and existing infrastructure and the first, specific reservoir designs. The planned reservoir parameters assumed its surface area of approx. 10.1 ha, maximum assumed water level elevation: 228.9 m above sea level and extraordinary assumed water

level elevation: 229.3 m above sea level, extraordinary capacity (at the level of 229.30 m above sea level): approx. 152,600 m³, maximum capacity (at the level of 228.90 m above sea level): approx. 131,600 m³. The reservoir serves recreational and flood control purposes. The latter was first used in September 2024 during heavy rainfall, capturing excess water and preventing it from feeding Ostropka, which is located below.

METHODOLOGY

The quality of surface waters in the Doa Stream catchment area was determined on the basis of field studies and physicochemical analyses of water conducted from April 2023 to February 2024. Water samples were collected frequently. The sampling locations were selected to represent diverse hydrological conditions in the catchment area (Fig. 2). Measurement point No. 1 was located at a spring, located in the Ostropa district, behind a private plot at 545 Daszyńskiego Street (50°16'38.8"N 18°35'12.7"E). Measurement point No. 2 was designated before the Gliwice Garrison Training Ground (50°16'28.2"N 18°36'34.5"E). Measurement point No. 3 was located behind the Gliwice Garrison Training Ground (50°16'29.4"N 18°37'45.3"E). Measurement point no. 4 was located just behind the newly built flood protection reservoir at the so-called Wilcze Doły (50°16'45.0"N 18°38'57.8"E). Measurement point no. 5 was designated at the place where the stream flows into the canalized section, at Nowy Świat Street (50°17'16.0"N 18°39'27.8"E).

Field studies included measurements of pH, electrical conductivity and dissolved oxygen. pH was measured using a CP-401 pH meter and CP-401 electrodes from Elmetron with an accuracy of 0.01 pH. Electrical conductivity was measured and read by a CC-401 conductivity meter with dedicated electrodes, and the read

values were accurate to 1 µS/cm. Dissolved oxygen and oxygen saturation were measured and read by a WTW Oxi 330 oxygen meter with an OxiCal SL electrode. Among the chemical parameters, determinations of nutrient indicators were performed – nitrates, phosphates and salinity indicators – sulphates, magnesium, calcium, sodium, potassium, chlorides. The choice of the range of parameters for laboratory determinations was dictated by the fact that these are the most characteristic parameters for assessing water quality, as well as the possibility of using them to calculate the Nemerow water quality index [20]. Nitrate and chloride concentrations were determined using an ion-selective electrode. Phosphates were determined by colorimetric method using a DR 3900 spectrophotometer. Sulfates were determined using the same spectrophotometer using the turbidimetric method. Sodium and potassium content was determined by flame photometry using a Remed FPM-871EM flame photometer. Information on magnesium and calcium content was obtained by titration with EDTA.

The Nemerow index is calculated based on the so-called single pollution index factors, which determine the relationship between the measured values of individual physicochemical parameters and the permissible values. The upper limit of the natural hydrochemical background or values specified in the relevant legal acts can be assumed as permissible values [21, 22]. Single pollution factors were calculated according to the formula:

$$P_i = \frac{C_i}{S_i}$$

P_i represents the pollution index of single water quality index i ; C_i is the measured value of pollutant content (mg · dm⁻³); S_i is the limit value of environmental quality on the basis of the legal act (mg · dm⁻³).

Based on the results obtained, the value of this index is classified as follows (Table 1):

Tab. 1

The classification of the single factor pollution index.

Water quality level	P_i	Pollution assessment
I	≤ 1	No pollution
II	(1,2]	Slightly pollution
III	(2,3]	Lightly pollution
IV	(3,5]	Moderately pollution
V	≥ 5	Seriously pollution

The Nemerow index takes into account the highest value of the single pollution factor index and the average value of all results obtained for a given sample. This index is calculated using the following formula:

$$P_N = \sqrt{\frac{(P_i)^2 + (P_{imax})^2}{2}}$$

In the formula, P_N is the comprehensive pollution index of the sampling point; P_{imax} is the maximum value of the single-item pollution index of the pollutants at the sampling point; P_i is the average value of the single-factor index. The classification of waters based on this index is in accordance with Table 2.

The classification of the Nemerow index.

Water quality level	P_N
I	<0.59
II	[0.59-0.74)
III	[0.74-1.00)
IV	[1.00-3.50)
V	>3.50

This indicator was calculated for individual measurement series for parameters included in the Regulation of the Minister of Infrastructure of 25 June 2021 on the classification of ecological status, ecological potential and chemical status and the method of classifying the status of surface water bodies, as well as environmental quality standards for priority substances [23], taking into account the limit value of the water quality indicator appropriate for class one in relation to rivers of type no. 9 - small carbonate upland river. The limit values taken into account were temperature 22 °C, electrical conductivity 364 $\mu\text{S}/\text{cm}$, pH 8.2, oxygen 8.8 $\text{mg} \cdot \text{dm}^{-3}$, sulphates 31.6 $\text{mg} \cdot \text{dm}^{-3}$, chlorides 13.3 $\text{mg} \cdot \text{dm}^{-3}$, nitrate nitrogen 1.3 $\text{mg} \cdot \text{dm}^{-3}$, phosphorus 0.053 $\text{mg} \cdot \text{dm}^{-3}$, calcium 68.3 $\text{mg} \cdot \text{dm}^{-3}$, magnesium 5.0 $\text{mg} \cdot \text{dm}^{-3}$.

RESULTS AND DISCUSSION

In the case of flowing waters, the water temperature is similar along the entire length of the stream. Each inflow of sewage or other waters with different temperatures results in temperature differences in the cross-section of the river or stream. All waters with

different temperatures mix at a later stage of flow in the bed. Water temperature has a large impact on the biocenosis of waters, as well as on the chemical processes occurring in them. When the temperature increases, the toxicity of other substances contained in it also increases, including heavy metals, pesticides, and at the same time affects the increased sensitivity of aquatic organisms to toxicants. The increase in temperature affects the decrease in the ability to dissolve oxygen. The water temperature in the Doa stream during the year reached the highest values in the summer months and the lowest in the winter months (Table 3). The highest recorded water temperature was 19.6°C in June at measurement point no. 4, while the lowest was 0.5°C recorded at points no. 3 and 5 at the beginning of December. The greatest temperature variation was observed in October and December 2023, when the amplitude was approximately 4.5 °C. Relating the temperature values in the Doa Stream to the values given in the regulation, it should be stated that it meets the criteria for class I water quality classification.

Tab. 3

Temperature values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	2.12.2023	29.12.2023	17.02.2024
1	7.3	-	-	-	5.0	5.7	6.1
2	10.0	18.3	-	-	4.3	5.9	6.8
3	10.4	18.6	18.5	12.3	0.5	4.8	7.0
4	10.6	19.6	18.5	16.9	1.2	5.9	7.1
5	10.1	18.1	18.7	14.7	0.5	6.1	7.6

The pH of water determines the degree of its acidity or alkalinity and depends on the proportion of hydrogen ions to hydroxide ions. The pH of water is of significant sanitary importance for biological organisms that are threatened in an environment that is too acidic or too alkaline. It also affects the release of many hazardous substances, including heavy metals from sediments [24]. In the studied stream, the pH values increased in most cases along its course (Table 4), the exception being measurement point no. 4, where in April and October the values were higher than at measurement point no. 5. The values were higher in August and October, lower in April

and in the winter months. At measurement point no. 1 they did not exceed pH 6, and the lowest value was 5.5, while the highest values are observed at points no. 4 and 5, and the highest of them is 8.2. Average pH values in the annual course were relatively even, fluctuating between the lowest average - 6.9 at the end of December and the highest - 7.8 in August. In some cases, the pH was too low to classify the stream as first or second quality class.

Tab. 4

pH values in measurements points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	2.12.2023	29.12.2023	17.02.2024
1	6.0	-	-	-	5.8	5.8	5.5
2	6.6	6.8	-	-	6.7	6.5	7.3
3	7.5	7.1	7.1	7.1	7.0	7.0	7.3
4	8.1	7.6	8.1	8.1	8.0	7.6	7.4
5	8.1	7.8	8.1	7.9	8.2	7.7	7.6

The electrolytic conductivity of an aqueous solution refers to its ability to conduct electric current, which occurs through the movement of ions. The higher the concentration of ions, the higher the conductivity of the solution, while very pure water conducts electric current poorly. In natural waters, ions mainly come from the dissociation of inorganic compounds. The higher the conductivity value, the greater the share of pollutants in the water. Electrolytic conductivity remained relatively at a similar level throughout the measurement period (Table 5). The exception are the results from December 2, where electrolytic conductivity achieved higher results, the highest of which were recorded at measurement points no. 4 and 5, at 1260 $\mu\text{S}/\text{cm}$ and 2130 $\mu\text{S}\cdot\text{cm}^{-1}$, respectively. Due to the exceptional snowfall and the resulting need to

use road salt to remove snow from the unit, it was decided to conduct an additional water analysis outside the planned two-month cycle to assess the impact of unusual weather conditions on the stream water. The average values of electrolytic conductivity oscillate between 456 $\mu\text{S}\cdot\text{cm}^{-1}$ (February) and 646 $\mu\text{S}\cdot\text{cm}^{-1}$ (October) and the highest average value - 1064 $\mu\text{S}\cdot\text{cm}^{-1}$ (early December). Electrolytic conductivity in the waters of the Doa stream shows significant fluctuations depending on the month and the measurement point, which makes it difficult to unequivocally assign waters to a specific quality class.

Tab. 5

Electrical conductivity values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	2.12.2023	29.12.2023	17.02.2024
1	456	-	-	-	687	524	431
2	629	412	-	-	586	431	375
3	426	427	438	553	656	425	383
4	559	554	550	647	1 260	563	517
5	594	599	533	737	2 130	601	574

Dissolved oxygen is of fundamental importance for all chemical and biochemical processes occurring in natural waters [25]. It is crucial for the life of fish and other organisms inhabiting waters. The solubility of pure oxygen in water at a temperature of 20°C and a pressure of 1013.25 hPa is equal to 43.8 mg·dm⁻³. The solubility of oxygen in water varies depending on temperature - when the temperature increases, the solubility of oxygen decreases. The solubility of oxygen is also affected by an increase in salinity - the higher the salinity, the lower the solubility, as well as atmospheric pressure - if the pressure decreases, the solubility of oxygen in water also decreases. The decreasing amount of oxygen dissolved in water is influenced by sewage. Water supersaturation with oxygen occurs when the concentration of oxygen in water is higher than the concentration corresponding to the equilibrium state at the corresponding pressure and temperature. The reason for the occurrence of supersaturation may be a sudden increase in water temperature, a drop in atmospheric pressure, as well as photosynthesis. This phenomenon is characteristic in places where heated water is introduced, e.g. from power plants operating in an open cooling system, as well as behind dams (mainly high ones), where a sudden change in pressure occurs when the water overflows and, falling, takes air molecules with it, which are then introduced below the water surface with high pressure, and then, under conditions of increased pressure, in deeper places the molecules dissolve. When the water returns to the surface, the pressure decreases and gases become supersaturated, not only with oxygen, but also with nitrogen. For the aquatic biocenosis, both the phenomenon of water supersaturation with oxygen and its deficit are unfavourable [26].

When the oxygen content in the water is below 2-3 mg·dm⁻³, an oxygen deficit occurs, which affects fish kills and developmental dysfunctions of other aquatic organisms. When the water starts to lack oxygen, anaerobic conditions are created. The highest values at all points were observed in April, especially for measurement points no. 4 and 5, where the concentrations were 20.6 mg·dm⁻³ and 22.4 mg·dm⁻³, respectively (Table 6). The lowest values were recorded from June to October, especially at measurement point no. 3, where an oxygen deficit occurred in the specified months. From August to February, the values began to stabilize with small differences between the individual measurement points. The average concentration value shows a decrease from April to June, and then a gradual increase in the following months. The lowest average concentration occurred in June 2023 (7.3 mg·dm⁻³), after which it increased to 10.6 mg·dm⁻³ in February. There is a clear decrease in concentration from April to June, followed by an increase in subsequent months. The values of dissolved oxygen in the stream water show significant variation depending on the month and location of the measurement point. In the winter period, higher dissolved oxygen concentrations are observed, while in the summer months these concentrations are lower. In addition, higher dissolved oxygen values occur near the mouth of the stream compared to its source. Due to this variability, the classification of the stream water quality based on the dissolved oxygen parameter is not unambiguous.

Tab. 6

Oxygen values in measurements points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	2.12.2023	29.12.2023	17.02.2024
1	11.6	-	-	-	7.7	7.6	8.5
2	15.1	5.0	-	-	9.6	9.8	11.8
3	15.4	4.3	5.7	3.6	7.9	9.6	10.8
4	20.6	10.4	11.2	14.0	8.8	11.6	10.6
5	22.4	9.4	9.5	8.0	6.2	11.1	11.5

Nitrates are essential nutrients for aquatic plants, including phytoplankton. During the vegetation period, their concentration decreases significantly and increases again in winter. However, such a natural cycle can be disrupted by the inflow of municipal and industrial sewage, containing large amounts of nitrogen compounds [27]. The source of nitrogen compounds should also be sought in the widely used nitrogen fertilizers, which enter surface waters through surface runoff caused by atmospheric precipitation. The annual course of nitrate content in the Doa stream water is presented in Table 7. The nitrate content in the stream water was clearly the highest at measurement point no. 1 in April, December and February, and their values exceeded 150 mg·dm⁻³. In December, the highest nitrate contents were recorded at all measurement points, and the average for this month was 84.6 mg·dm⁻³. The lowest values were recorded from June to October. The lowest average value of nitrate concentration in the stream water is clear in October and

amounts to 6.4 mg·dm⁻³. Average nitrate concentrations decreased from April until October, then increased again in December and decreased again in February. Only at measurement point no. 3 in October does the concentration of nitrates allow the stream water to be classified as quality class II.

Tab. 7

Nitrates values in measurements points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	110.7	-	-	-	150.6	90.6
2	43.4	25.7	-	-	79.7	20.2
3	33.7	14.2	5.5	2.0	64.2	16.4
4	36.3	10.2	16.0	8.9	66.5	18.4
5	35.4	9.3	16.8	8.4	62.0	17.3

Phosphates can enter surface waters as a result of weathering and dissolution of phosphate minerals, soil erosion, inflow of municipal and industrial sewage, as well as surface runoff and atmospheric precipitation [28]. Additionally, waters used for fish farming are often enriched with phosphate fertilizers. Phosphates used as fertilizers are adsorbed on soil particles, and only a small part of them remains in the soil in a dissolved form in water. They enter surface waters mainly as a result of erosion, ending up in rivers together with suspensions. The presence of phosphates in surface waters is a serious problem because it contributes to the accelerated development of algae. Measured phosphate values do not exceed $0.5 \text{ mg} \cdot \text{dm}^{-3}$. This value was obtained only for measuring point no. 2 in June. Average phosphate concentration values increased from April to August, then decreased until December and started to increase again.

Sulphates are one of the most common anions in water, constituting the basic anionic component of surface waters, next to chlorides. Their presence in water is caused by the processes of rock and soil leaching, atmospheric

precipitation, biochemical oxidation of other forms of sulphur and sewage. Acidic mine waters and mineral fertilizers can also be a significant source of sulphates. Sulphates in standard concentrations do not affect the sanitary quality of water, but at their high levels they can change its taste [29]. In each of the months studied, the highest values are noticeable for points no. 4 and 5, the highest of which were recorded in October (Table 8). The lowest sulphate values were recorded for all months at measurement point no. 1 (for months in which the water flowed in the trough). The average values were lowest in April ($45.0 \text{ mg} \cdot \text{dm}^{-3}$), which increased in the following months until October ($80.2 \text{ mg} \cdot \text{dm}^{-3}$), then decreased in December and increased again from February. In the vast majority of the measurement year, the stream waters met the criteria for class II quality in relation to sulphate content.

Tab. 8

Sulphates values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	39.9	-	-	-	46.7	42.9
2	43.5	43.0	-	-	47.7	49.1
3	44.3	49.2	62.7	51.7	49.0	49.8
4	49.9	85.0	70.6	94.5	55.4	74.8
5	47.4	81.8	69.4	94.4	61.0	80.8

Magnesium salts are a permanent element of surface and underground waters, and their content depends primarily on leaching from rocks. Water contamination with magnesium from industrial sewage is rare [25]. An exception is sewage from soda production, which may contain large amounts of magnesium. In surface waters, magnesium content is usually lower than calcium. In the first two months, the lowest magnesium values were recorded in the stream water, of which in some cases the magnesium content did not exceed the detection limit. In the following months, the magnesium content was higher, especially in December at measurement point no. 3, where the amount of magnesium in the stream water was equal to $39.5 \text{ mg} \cdot \text{dm}^{-3}$, which is the highest value in the entire annual course. The average

values in April and June were $3.5 \text{ mg} \cdot \text{dm}^{-3}$ and $1.1 \text{ mg} \cdot \text{dm}^{-3}$, then increased in August to $12.0 \text{ mg} \cdot \text{dm}^{-3}$, and dropped slightly in the following months. Magnesium concentrations in the stream water show significant variability depending on the month and the location of the measurement point (Table 9).

Tab. 9

Magnesium values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	0.0	-	-	-	4.9	15.8
2	1.2	1.8	-	-	3.0	7.3
3	1.8	0.0	15.2	9.1	39.5	12.8
4	6.1	2.4	10.9	7.9	3.0	8.5
5	8.5	0.0	9.7	14.6	1.2	10.3

Calcium is one of the leading cations found in surface waters, and its concentration can reach several hundred $\text{mg} \cdot \text{dm}^{-3}$. Its presence in waters is the result of washing out and discharging municipal and industrial sewage. The concentration of calcium in water depends to a large extent on the carbonate balance, and its precipitation or dissolution from sediments depends on the prevailing physicochemical conditions. The highest calcium content was recorded in June at measurement point no. 5, while the lowest value was at measurement

point no. 1 in February (Table 10). Average values ranged between $74.5 \text{ mg} \cdot \text{dm}^{-3}$ (December) and $114.9 \text{ mg} \cdot \text{dm}^{-3}$ (October). From April to June, average values increased, then decreased from June to August, increasing again until October. In the next part of the year, average calcium values in the stream water decreased.

Tab. 10

Calcium values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	92.2	-	-	-	90.2	58.1
2	84.2	64.1	-	-	71.1	61.1
3	83.2	99.2	86.2	120.2	74.2	64.1
4	103.2	114.2	76.2	122.2	104.2	87.2
5	107.2	132.3	73.2	102.2	111.2	102.2

The sodium content in surface waters depends mainly on the processes of leaching rocks and soils. Sodium is used in households as table salt, as well as in various industries, such as chemical, food and medical. Increased sodium content in surface waters may result from the discharge of industrial and municipal sewage or the outflow of saline mine waters. Municipal sewage usually has a sodium concentration of $20\text{-}50 \text{ mg} \cdot \text{dm}^{-3}$.

Water from mine discharges, on the other hand, may contain even several hundred $\text{mg} \cdot \text{dm}^{-3}$ of sodium. Two high values stand out in the measurement sequence: in April at measurement point no. 2 with a value of $46.4 \text{ mg} \cdot \text{dm}^{-3}$ and in October at measurement point no. 5 with a value of $36.2 \text{ mg} \cdot \text{dm}^{-3}$ (Table 11).

Tab. 11

Sodium values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	6.3	-	-	-	6.0	5.2
2	46.4	23.4	-	-	6.4	7.4
3	8.0	5.9	8.0	7.3	5.6	5.7
4	15.3	12.1	25.3	20.8	8.8	9.1
5	18.1	15.3	25.0	36.2	12.8	14.3

Potassium is commonly found in surface waters, but usually in small amounts, not exceeding several $\text{mg} \cdot \text{dm}^{-3}$ [29]. In waters polluted by runoff from fields fertilized with potassium salts or some industrial sewage, the concentration of potassium can increase to several $\text{mg} \cdot \text{dm}^{-3}$. Potassium is usually present in water in concentrations lower than calcium, magnesium and sodium. The highest potassium content in the stream waters was recorded at measurement points no. 4 and 5 in August, and their values reached $24.6 \text{ mg} \cdot \text{dm}^{-3}$ and $22.6 \text{ mg} \cdot \text{dm}^{-3}$, respectively. The lowest potassium content was

visible at measurement point no. 3 during each of the months studied, and the values ranged between $2.8 \text{ mg} \cdot \text{dm}^{-3}$ and $5.8 \text{ mg} \cdot \text{dm}^{-3}$ throughout the study period (Table 12).

Tab. 12

Potassium values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	21.10.2023	29.12.2023	17.02.2024
1	8.2	-	-	-	5.5	8.7
2	8.9	15.7	-	-	7.1	7.8
3	2.8	4.7	4.9	2.9	5.8	5.6
4	5.2	5.2	24.6	8.2	4.6	4.4
5	4.4	5.2	22.6	7.3	5.6	5.5

Chloride ion occurs widely in nature, mainly in the form of sodium salt. However, the chloride content in rocks is low due to their high solubility in water. Additionally, chlorides enter rivers with industrial and municipal sewage and, to a large extent, with mine water. Chlorides in water are stable and do not undergo chemical or biochemical changes. Their concentration does not change during the standard sewage treatment process in river waters [18]. The chloride content of the tested waters

indicates that the average chloride content gradually decreased from about $80 \text{ mg} \cdot \text{dm}^{-3}$ in April to about $40 \text{ mg} \cdot \text{dm}^{-3}$ in February with a slight increase in October. The highest values were recorded in April at measurement point no. 2 (Table 13). Due to the high concentration of chlorides in the stream waters, it is not possible to assign it to any of the specific water quality classes.

Tab. 13

Chlorides values in measurement points.

Point	14.04.2023	24.06.2023	28.08.2023	r. 21.10.2023	r. 29.12.2023	r. 17.02.2024
1	49.0	-	-	-	52.0	43.0
2	165.0	125.0	-	-	43.0	41.0
3	58.0	53.0	51.0	42.0	35.0	20.5
4	72.0	68.0	68.0	62.0	58.0	41.0
5	66.0	76.0	55.0	96.0	58.0	49.0

The results for single pollution factors are quite diverse in all measurement points. The lowest values were obtained in the case of point no. 3. For this point, the lowest values were 0.01 (phosphorus) and the maximum in the dominant part of the year were equal to about 3.7 (nitrate nitrogen). The maximum value of the single pollution factor for this point was determined in December and amounted to 14.5 (nitrate nitrogen). In the case of point no. 1, all single pollution factor values for temperature, pH and phosphorus suggested no pollution, in the case of conductivity, oxygen, sulphates and calcium it was slightly pollution, values exceeding 3, which are equivalent to moderately pollution were calculated for chlorides and magnesium. The highest values, exceeding the value of 30 in December were recorded for nitrate nitrogen. This suggests serious pollution, and the limit value was exceeded almost 7 times. At measurement point no. 2, the lowest single pollution factor values were also obtained for phosphorus (0.01), and the highest, reaching

18 for nitrate nitrogen. Such values were found in December. Temperature and pH values at this point suggest no pollution. In the case of conductivity, oxygen, sulphates, calcium and magnesium, the factor values indicate slightly pollution (values do not exceed 2). The chloride content is so high that in December and February the single factor value should be classified as moderate pollution, and in April and June as seriously pollution (values exceeding 12 and 9, respectively). At point number 3 the highest values were obtained for nitrate nitrogen - single pollution factor exceeded the value of 14 (seriously pollution). At this point only in the case of temperature, phosphorus and pH no pollution was observed. The values of factors for conductivity, oxygen, sulphates and calcium indicate slightly pollution, while the remaining parameters reach values from 2.55 for magnesium to 4.36 for chlorides. It should be noted that in the case of this point there is the greatest time variability of factors. In this section, the stream bed is close to natural. To the north of

the stream there are allotment gardens, to the east and south there are fields. To the west, the stream is crossed perpendicularly by an access road, while behind it there is a floodplain forest, to the west there is an artificial reservoir supplied with water from the Doa stream. The diversification of water quality in this section may be influenced by spatial development and the use of fertilizers, waste from allotment gardens and pollution from transport. In the fourth measurement point, the values of single pollution factors start from 0.01 for phosphorus and reach about 15 for nitrate nitrogen. Values exceeding 5 and indicating serious pollution were recorded for chlorides. No impact of pollution on water quality can be determined only for temperature, pH and phosphorus. Values for magnesium and conductivity do not exceed 2, but the other components indicate moderate pollution. In the last point, similarly to the previous one, the lowest factor values were recorded for phosphorus, and the highest for nitrate nitrogen (around 14). The remaining components show trends similar to those in point no. 4.

In all observation points the highest values of single pollution factors for nitrate nitrogen were observed in the early spring and winter months and the highest values of factors for chlorides in the summer and autumn months. The temporal variations in nitrogen can be attributed to the higher nitrogen uptake in rivers and denitrification rates in summer compared to winter [30]. In the case of spring months, higher nitrate content may be due to the use of fertilizers. Higher chloride content during summer months may be related to low flow conditions during dry summer and in October to the periodic application of road salt.

For all measurement points, the Nemerow index values were also calculated. The results are presented in Fig. 2. As can be seen, the highest values of this index in spring and winter were calculated for the starting point. From the north, the area around the point is urbanized, there are residential buildings, as well as automotive companies. From the south, east and west, the point is surrounded by agricultural fields. The riverbed in this place resembles a drainage ditch. In the case of the summer and autumn months, the values are close to zero, which indicates no impact of pollution on the quality of the stream. In the second point, in the spring and winter months, the Nemerow index values drop by about 50%. In the summer, on the other hand, the value of this index is about 6 times higher in the second point than in spring, mainly due to chlorides. In the third point, the index value drops for all seasons except autumn. In the entire analyzed period of time, there was an increase in the Nemerow index between points 3 and 4. It should be noted that point no. 4 is located at the stream flow through the retention reservoir. This suggests a deterioration in water quality after flowing through the reservoir. The values obtained for the Nemerow index do not indicate a high differentiation between point three and four, but individual observations such as the conductivity value in December 2023, which is twice as high at point 4 than at point 3, provide a basis for further analysis of the issue. At point five, an increase was noted in the summer and autumn months and a decrease in spring and winter between points 4 and 5. To sum up the obtained values of this index for the analyzed waters, it should be stated that it classifies these waters into water quality levels IV and V.

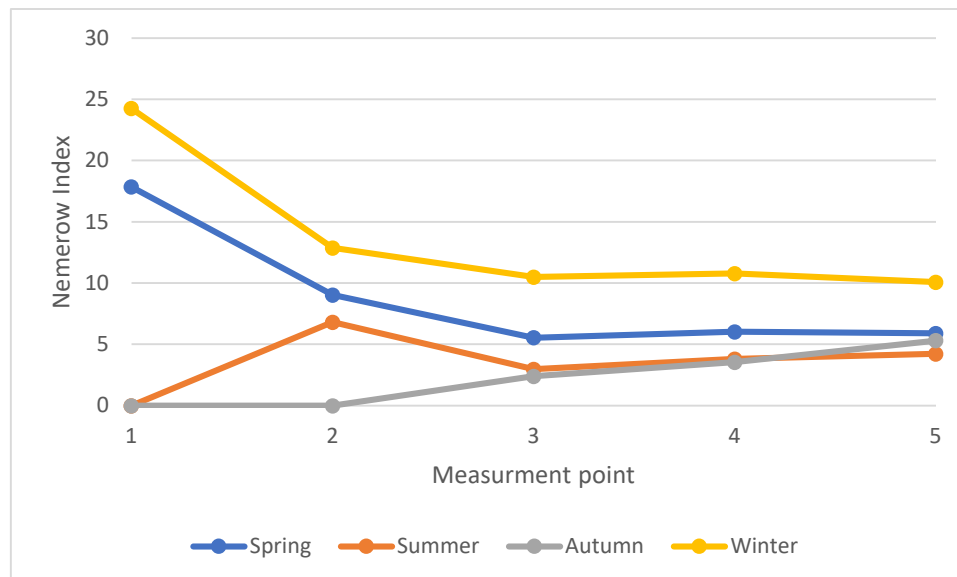


Fig. 2 Nemerow indices values.

SUMMARY AND CONCLUSIONS

The Doa stream catchment area is one of the last natural areas in Gliwice, which makes it the subject of a conflict between the need to build flood protection infrastructure and environmental protection. The construction of a dry retention reservoir caused controversy, especially among the local community, which criticized the investment as an interference in a valuable recreational area. The dry retention reservoir on the Doa stream, commissioned in early 2024, had the opportunity to demonstrate its functionality during the heavy rainfall in September 2024, associated with the Genoese low. Thanks to the closure of the outlet and damming of water from the catchment area, no flooding was recorded in the protected area. The investment fulfilled its function, but the planned future development of the areas around the reservoir may reduce the ability of the ground to absorb rainwater, increasing the load on the reservoir. Its current size is, however, assessed as sufficient to protect lower-lying areas from flooding. The Doa stream is exposed to the influence of both natural and anthropogenic factors that affect its chemical composition and ecological condition.

Field studies and physicochemical analyses have shown a clear seasonality of physicochemical parameters, resulting from both natural annual cycles and anthropogenic impacts. The concentrations of sulphates, chlorides and sodium showed clear spatial and temporal differences, indicating the impact of human activity, and electrolytic conductivity reflected the variable level of dissolved substances. Increased concentrations of mineral components, such as calcium and magnesium, confirm the anthropogenic impact on water. Particularly disturbing are the oxygen deficits and increased concentrations of biogenic compounds, which may negatively affect the aquatic ecosystem. Water pollution in the stream and environmental threats have also shown high values of the Nemerow index. In this area, it is recommended to continue monitoring physicochemical indicators of water, including biogenic substances and salinity, in order to assess the impact of the investment and natural factors on the state of the ecosystem, and to comprehensively assess whether the reservoir does not cause a negative impact on local ecosystems, especially in the context of hydrological changes, water quality and biodiversity.

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Marek Ruman

Uniwersytet Śląski, Wydział Nauk Przyrodniczych
Będzińska 60, Sosnowiec