

# Temporal and spatial changes in pH values and phosphate phosphorus concentrations in the Bocegaj watercourse and their impact on fish life

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Between 2022 and 2024, they were monitored in the Bocegaj watercourse, where pH and phosphate phosphorus ( $P-PO_4^{3-}$ ) concentrations were measured. During the period under review, pH values were relatively stable, and the average value reached 7.69. Seasonal changes indicated higher pH values in winter and summer, which may have been caused by reduced biological activity in winter and increased photosynthetic activity of aquatic organisms in summer. Spatial analysis showed that the most stable pH values were recorded below the pond outflow into the stream, while the most pronounced increase occurred in the northwestern part of the pond. The average concentration of phosphate phosphorus for the entire period under study was  $0.52 \text{ mg} \cdot \text{dm}^{-3}$ . The highest concentration was recorded in June and the lowest in April. Spatial differences indicated a substantial increase in phosphate phosphorus concentrations at the sampling site located below the wastewater treatment plant outflow. According to the Regulation of the Government of the Slovak Republic No. 269/2010 Coll., the water in the Bocegaj watercourse and in the Koliňany pond meets the criteria for the breeding and life of cyprinid fish in terms of pH but does not meet these requirements in terms of phosphate phosphorus concentrations.

**Keywords:** brook, government regulation, pH, phosphates phosphorus, pond

## 1 Introduction

Water quality is affected by anthropogenic (industrial, agricultural) and natural processes, including precipitation, weathering, erosion, mineral deposits and other geological phenomena (Onojake et al., 2011). Surface waters are the most susceptible and vulnerable water bodies to contamination due to exposure to various types of waste and runoff (Singh et al., 2005).

The pH values of natural and artificially created waters are influenced by many factors that also affect other water quality parameters (Weiner, 2008). Most natural changes result from interactions with surrounding rocks (especially carbonates) and other materials. The pH values of surface waters can also fluctuate due to acid precipitation and the impact of wastewater or mine discharges (Hicking, 1995). The pH values of unpolluted surface waters usually range from 6 to 8.5. Low pH values of water most often occur in the spring during snowmelt. Conversely, high values are found in eutrophic ponds

(Adamec et al., 2016). Water alkalinity increases in soils rich in carbonates and bicarbonates (such as limestone) and decreases due to wastewater runoff and aerobic respiration (Perlman, 2014). Water pH values are also important for the life of aquatic organisms. If the pH of water is very high or very low, aquatic organisms living in it die (Fondriest Environmental, 2013; Saalidong et al., 2022).

Phosphorus is the most important nutrient controlling plant growth in aquatic ecosystems (Immerová, 2012). Phosphorus concentrations are relatively low in natural waters. The solubility of mineral forms of phosphorus is regulated by pH values. Its increased concentrations in natural waters due to human activities usually stimulate the growth of aquatic plants, especially phytoplankton. Phosphorus pollution of surface waters is one of the most widespread and serious water pollution problems. The main sources of phosphorus in water are phosphorus-containing minerals, e.g. iron, aluminium and calcium

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phosphates (Boyd, 2015). Sources of surface water phosphorus pollution are divided into point and diffuse sources. Point sources include the natural decomposition of phosphate-containing rocks and minerals, wastewater treatment plants, industrial areas, erosion, atmospheric deposition, agricultural runoff and stormwater runoff. Diffuse sources include agricultural activities and nutrient leaching from soil (Hu et al., 2019). High concentrations of phosphorus in aquatic ecosystems can lead to poor ecological status of surface waters and, because of oxygen deficiency, to eutrophication (Kiemle & Fuchs, 2022).

The aim of the work was to evaluate temporal and spatial changes in pH values and phosphate phosphorus concentrations in the Bocegaj watercourse and in the Koliňany pond and their impact on the life and reproduction of fish, and subsequently compare them with the values specified in the Regulation of the Government of the Slovak Republic No. 269/2010 Coll.

## 2 Material and Methods

### 2.1 Characteristics of the monitored area

The village of Koliňany (Geographic coordinates: 48° 35' 92.48" N, 18° 19' 42.92" E) is located approximately 10 km southwest of the city of Nitra, at an elevation ranging from 170 m a.s.l. to 356 m a.s.l., with an area of 1,250 ha. From an agricultural perspective, the village belongs to the alfalfa–barley–wheat production region. In crop production, barley, wheat, and fodder crops predominate. The village is also an important viticultural area; vineyards totalling 13.8 ha are situated on the southern slope of the Koliňany Hill. The total area of agricultural land in the village accounts for 80% of the cadastral territory.

The Bocegaj watercourse flows through the village; it originates above the village of Žirany, at the foot of Mount Cigáň. It is a right-hand tributary of the Drevenica stream, which itself is a tributary of the Žitava River. Within the village's cadastral territory, the Koliňany water reservoir, with a total area of 9.8 ha, has been constructed on the Bocegaj stream. The function of this water area is irrigation management. According to the climatic classification, the area falls within a warm climate region. The average annual temperature is 10 °C, and the average annual precipitation is 580 mm.

### 2.2 Determination of Sampling Sites

Water samples were collected between 2022 and 2024, approximately midway through each month. Six sampling sites were selected to determine pH values and phosphate concentrations:

1. Sampling site 1 – Located 50 m upstream from the wastewater treatment plant. Water depth was 0.3 m. Vegetation in the vicinity included willows (*Salix alba*), dog rose (*Rosa canina*), and various species of grasses.
2. Sampling site 2 – Located below the wastewater treatment plant outflow into the pond. The area is overgrown with willows (*Salix alba*). The water at this site appeared visually polluted.
3. Sampling site 3 – Located at the inlet of the stream into the pond. Vegetation includes willows (*Salix alba*) and poplars (*Populus alba*).
4. Sampling site 4 – Located in the northwestern part of the pond, dominated mainly by stands of various grass species.
5. Sampling site 5 – Located in the lower part of the pond. The edges of this area are covered by tree vegetation, primarily willows (*Salix alba*) and poplars (*Populus alba*).
6. Sampling site 6 – Located below the outflow of the pond into the stream.

In the collected water samples, pH values were determined potentiometrically using the inoLab Multi Level 3 device, which is based on the direct measurement of the electromotive force of the cell formed by the pH indicator electrode and the reference electrode immersed in the water sample. Phosphate phosphorus concentrations were determined photometrically using WTW nitrospoeptical with sulfuric acid. The principle of the method is that orthophosphates in an acidic environment react with sodium or ammonium molybdenum to form phosphomolybdic acid, which is subsequently reduced by ascorbic acid to an intensely colored molybdenum blue. The intensity of the color is directly proportional to the concentration of phosphorus in the water sample.  $P-PO_4^{3-}$  concentrations were expressed in  $mg \cdot dm^{-3}$ . The obtained results were compared with the values specified in the Government of the Slovak Republic No. 269/2010 Coll., which lists the quality indicators for surface waters suitable for the life and reproduction of native fish species. The obtained results were processed using mathematical and statistical methods (Statgraphics 5.0 plus program).

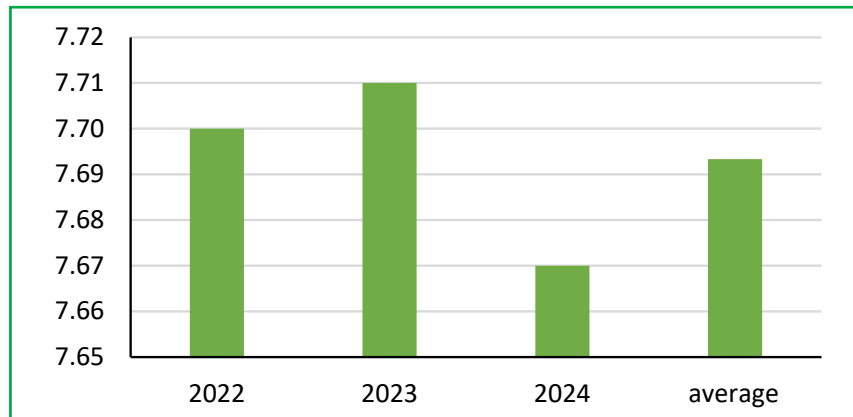
## 3 Results and Discussion

In the period from 2022 to 2024, the pH values of the water were monitored in the Bocegaj watercourse and in the Koliňany pond. The results showed low variability, with values ranging from 7.67 (2024) to 7.71 (2023), and an overall average of 7.69 (Figure 1). The slightly alkaline reaction found, which was in the range of 7.55–8.0, corresponds to values that are typical for

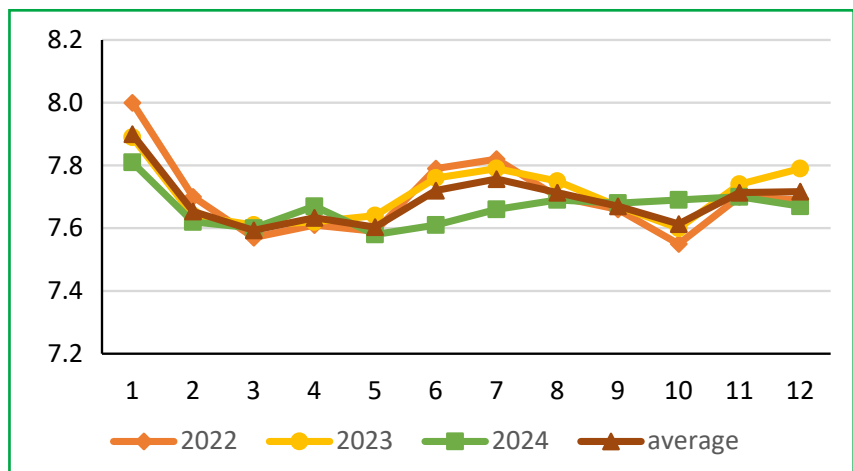
many surface waters. Compared to our results, Saalidong et al. (2022), and Antalová (2025) in the Nitra river basin report lower pH values. It can be stated that the determined water reaction values are favourable for fish farming, as they range from 6.5 to 8.5, which is a neutral or slightly alkaline water reaction (Humpl & Pivnička, 2006; Adamec et al., 2016; Policar et al., 2018).

The seasonal dynamics of pH showed average values ranging from 7.59 (March) to 7.90 (January). A significant decrease was recorded in February and from July to October, while a slight increase was observed from May to July and in November (Figure 2). The summer increase in pH is probably related to the intensive photosynthetic assimilation by aquatic organisms, which results in the absorption of carbon dioxide and a subsequent shift toward alkalinity. Higher values in winter can be attributed to inhibited biological activity, as confirmed by Boyd (2015), who reported that pH increases with decreasing temperature. In the other months, pH differences were insignificant. An alternative explanation for the increased pH may also be hydrochemical parameters, particularly calcium, sulfate, and total conductivity, according to Saalidonga et al. (2022), and Armaha et al. (2020).

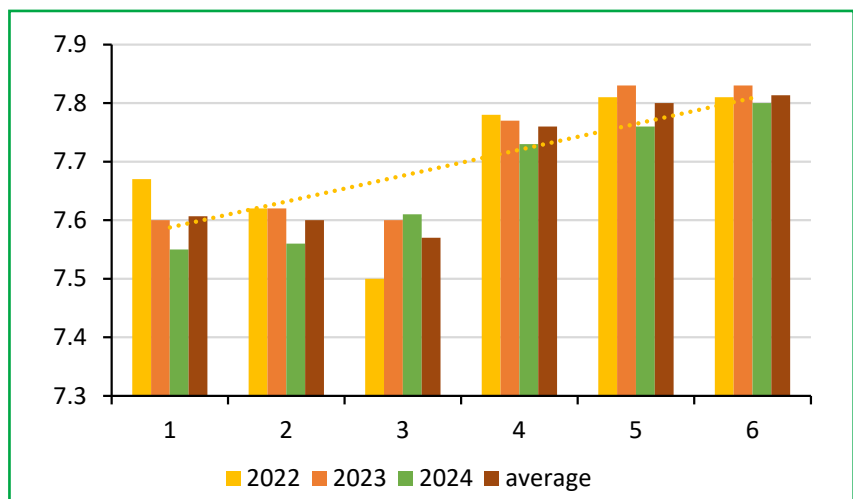
The average pH values also showed spatial variability of pH values, which varied in the range from 7.57 (sampling site no. 3) to 7.81 (sampling site no. 6). Sampling site no. 6, situated below the mouth of the pond, can be considered the most stable, where no significant interannual differences were observed during the monitored period. On the contrary, a trend of long-term increase in pH values was identified at sampling site no. 3, while the most pronounced gradation of its average values was recorded at sampling site no. 4, situated in the northwestern part of the pond (Figure 3).



**Figure 1** Average pH values during the years 2022–2024



**Figure 2** Average pH values in relation to sampling time



**Figure 3** Average pH values in relation to sampling site

**Table 1** Analysis of variance for values of pH

| Effect              | The sum of squares | Degrees of freedom | Mean square | F-value | P-value  |
|---------------------|--------------------|--------------------|-------------|---------|----------|
| Year                | 0.000027           | 1                  | 0.000003    | 0.0012  | 0.003281 |
| Month               | 0.023132           | 3                  | 0.003426    | 1.3215  | 0.015372 |
| Sampling site       | 0.018762           | 3                  | 0.005891    | 0.6127  | 0.025814 |
| Year*Month          | 0.025346           | 2                  | 0.003651    | 0.5326  | 0.038162 |
| Year*Sampling site  | 0.024365           | 4                  | 0.004367    | 0.8465  | 0.023598 |
| Month*Sampling site | 0.523684           | 5                  | 0.003258    | 0.7315  | 0.036251 |
| Error               | 0.261152           | 2                  | 0.002657    |         |          |

Analysis of variance showed a statistically insignificant effect of location on pH values. On the contrary, a significantly significant effect of the month of sampling was found, which depends on the biological activity of aquatic organisms during the growing season. The effect of year was statistically significant (Table 1).

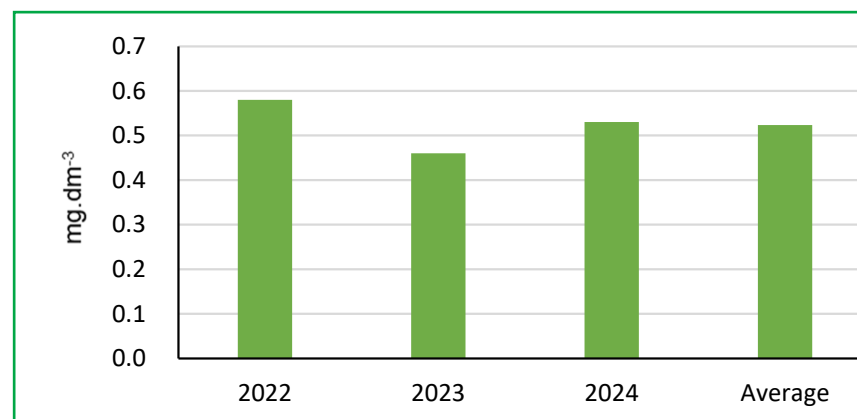
Regarding the hydrogen ion concentration (pH), the measured values at the studied locations complied with the requirements of the Government Regulation of the Slovak Republic No. 269/2010 Coll. This regulation establishes a limit range of 6.00–9.00 for waters suitable for the life and reproduction of cyprinid fish species. Consequently, it can be concluded that the water quality for this indicator meets the criteria for the breeding, physiological needs, and habitat of cyprinid fish.

The average concentrations of phosphate phosphorus fluctuated in the range from 0.46 (year 2023) to 0.58 (year 2022)  $\text{mg}\cdot\text{dm}^{-3}$ , while its total average for the monitored period reached the value of 0.52  $\text{mg}\cdot\text{dm}^{-3}$  (Figure 4). In the year-on-year comparison between 2022 and 2023, a decrease in its concentration of 20.7% was recorded, after which a further increase in the concentration of phosphate phosphorus by 15.2% was recorded in the following period (2023–2024).

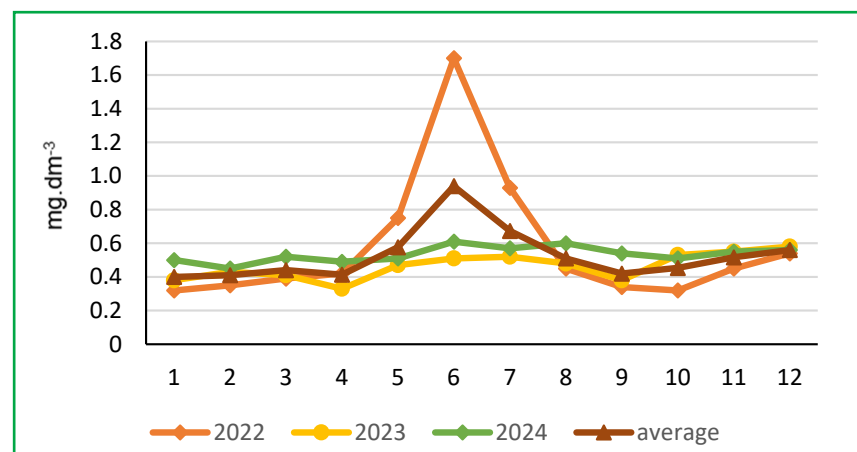
In terms of seasonal dynamics, the maximum average concentration

of  $\text{P-PO}_4^{3-}$  was recorded in June (0.94  $\text{mg}\cdot\text{dm}^{-3}$ ), while the minimum values (0.41  $\text{mg}\cdot\text{dm}^{-3}$ ) were identified in February and April. During the spring period, concentrations showed slight fluctuations, with a maximum in May (0.58  $\text{mg}\cdot\text{dm}^{-3}$ ). The highest average values were observed in the summer period, with the absolute maximum recorded in June 2022 (1.70  $\text{mg}\cdot\text{dm}^{-3}$ ).

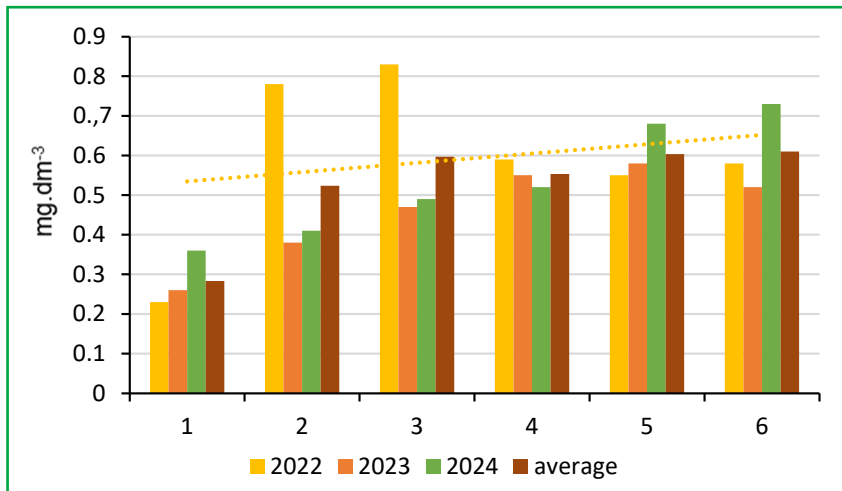
This increase is probably related to higher water temperatures, a precipitation deficit (lower flow), and the subsequent progression of eutrophication. The seasonal trend of higher phosphate concentrations in the summer months corresponds to the findings of Sabová (2020) in the Ratka reservoir area, as well as Biedunková et al., (2025) in the Shtyr River basin in Ukraine. According to



**Figure 4** Average concentrations of  $\text{P-PO}_4^{3-}$  ( $\text{mg}\cdot\text{dm}^{-3}$ ) during the years 2022–2024



**Figure 5** Average  $\text{P-PO}_4^{3-}$  concentrations ( $\text{mg}\cdot\text{dm}^{-3}$ ) depending on the sampling time



**Figure 6** The mean concentrations P-PO<sub>4</sub><sup>3-</sup> (mg·dm<sup>-3</sup>) as dependent on sampling site

Hejzlar et al. (2015), the increased phosphorus concentrations in the summer period may be due to mineralisation of freshly de-sedimented biomass and not to release from older sediments. An alternative explanation is the leaching of phosphorus from the soil horizon due to torrential rainfall (Wojciechowska et al., 2019). In September, average concentrations decreased, followed by a progressive increase from October to December (Figure 5).

The spatial variability of the average P-PO<sub>4</sub><sup>3-</sup> concentrations ranged from 0.28 (sampling site no. 1) to 0.61 mg·dm<sup>-3</sup> (sampling site no. 6). A significant increase in values by 79.31% was identified at sampling site no. 2, located immediately below the outlet of the wastewater treatment plant into the pond. This fact indicates insufficient

efficiency of the tertiary treatment stage aimed at eliminating nutrients, specifically phosphorus compounds. To achieve the required effluent wastewater quality and mitigate the anthropogenic load on the pond, it seems necessary to implement phosphorus precipitation. Wastewater from municipal wastewater treatment plants represents stationary point sources of pollution, the ecotoxicity and degree of impact on the recipient of which are directly correlated with the quantitative and qualitative composition of the discharged pollutants (Zhang et al., 2023). No significant differences in phosphate phosphorus concentrations were observed among the other monitored locations (Figure 6).

The results of the analysis of variance for phosphate phosphorus confirmed a significant effect of

month. On the other hand, the effects of year and sampling location were statistically insignificant (Table 2).

The detected phosphate concentrations in the pond exceed the limit of 0.4 mg·dm<sup>-3</sup>, which is determined as optimal for the life and reproduction of cyprinid fish (Adamec et al., 2016; the Regulation of the Government of the SR No. 269/2010 Coll.). From this indicator's perspective, the given environment does not meet the conditions for successful fish breeding and reproduction.

#### 4 Conclusions

During the years 2022–2024, pH values and phosphate phosphorus concentrations were monitored in the Bocegaj stream and Koliňany pond. The average pH value over the entire monitored period was 7.69. The pH values were slightly alkaline throughout the period (7.55–8.00), which is typical of many surface waters. The most pronounced pH fluctuations occurred in winter and summer. Based on the results, interannual changes in pH were minimal, and the water exhibited stable chemical properties over the long term. Sampling sites located in the lower part of the pond and below the pond outflow into the stream consistently showed the highest and most stable pH values, suggesting a smaller impact of environmental factors or more effective self-purification of the water. The largest increase

**Table 2** Analysis of variance for concentrations of P-PO<sub>4</sub><sup>3-</sup>

| Effect              | The sum of squares | Degrees of freedom | Mean square | F-value | P-value  |
|---------------------|--------------------|--------------------|-------------|---------|----------|
| Year                | 0.000003           | 2                  | 0.000003    | 0.0009  | 0.866582 |
| Month               | 0.083162           | 1                  | 0.006598    | 2.0863  | 0.040362 |
| Sampling site       | 0.031748           | 1                  | 0.002082    | 0.8355  | 0.722061 |
| Year*Month          | 0.052634           | 4                  | 0.002048    | 0.6276  | 0.759623 |
| Year*Sampling site  | 0.026824           | 1                  | 0.002268    | 0.9425  | 0.552394 |
| Month*Sampling site | 0.351042           | 4                  | 0.002215    | 0.8772  | 0.874436 |
| Error               | 0.305230           | 3                  | 0.003262    |         |          |

in average pH was observed in the northwestern part of the pond. The average concentration of  $\text{P-PO}_4^{3-}$  over the entire monitored period was  $0.52 \text{ mg} \cdot \text{dm}^{-3}$ , which can already be considered an indicator of eutrophication. The most significant increase in phosphate phosphorus was recorded in the summer, mainly in June. Low concentrations were observed during spring and winter. Interannual fluctuations were minor. The highest average concentrations were found at the stream's confluence into the pond and in the lower part of the pond, while the lowest values were recorded upstream of the wastewater treatment plant. Among the other sampling sites, no significant differences in average phosphate phosphorus concentrations were observed over the monitored years.

### Acknowledgment

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