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REDUCTION OF NITRATE NITROGEN AND ORGANIC MATTER IN WATER RESERVOIR ISOLATED BY A FLOATING BARRIER USING A SAND-GRAVEL FILTER COMBINED WITH ION EXCHANGE RESINS

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ABSTRACT

Aim of the study

Cyanobacterial blooms lead to an increase in organic matter and higher concentrations of Biochemical Oxygen Demand over 5 days (BOD_5) and Chemical Oxygen Demand (permanganate method) (COD_{Mn}), simultaneously causing oxygen depletion. In addition, rising pH levels may adversely affect the functioning of the aquatic ecosystem. The aim of this study was to evaluate the effectiveness of the Water Quality Improving Installation (WQII) in reducing (nitrate nitrogen) NO_3-N concentrations and changing the organic matter content and pH of the water separated by a fin boom in a reservoir.

Material and methods

Generalized linear models (GLMs) were applied for NO_3-N, BOD_5, and COD_{Mn} and pH.

Results and conclusions

The results showed a statistically significant decrease in NO_3-N level at the tap outlet compared with the level at the pipeline inlet. For the remaining parameters (pH, BOD_5, COD_{Mn}), no statistically significant differences were observed, although a favorable downward trend in values was noted at the outlet of the installation. Measurements of NO_3-N reduction efficiency showed markedly higher effectiveness in water collected directly from the installation tap (median 70%) compared to samples from the reservoir (median 39.4%), suggesting that the water in the reservoir is partially mixed. Reducing NO_3-N and organic matter limits the availability of nutrients for phytoplankton and reduces oxygen consumption, contributing to the stabilization of the ecosystem and the improvement of the ecological quality of the studied reservoir. The results confirm the effectiveness of the applied installation in improving water quality parameters and reducing the risk of eutrophication.

Keywords: ion exchange, water reservoir, fin boom, remediation, eutrophication

INTRODUCTION

Anthropogenic eutrophication is currently one of the most serious water quality problems in most freshwater and marine ecosystems worldwide (Zamparas and Zacharias, 2014). A significant group of compounds responsible for algal blooms are nutrients. Their excessive concentrations in water lead to a deterioration of its quality. This phenomenon is particularly visible from spring to autumn, when more intense eutrophi-

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cation of waters is observed (Moraczewska-Majkut et al., 2022; Wiatkowski et al., 2018). Cyanobacterial blooms disrupt aquatic ecosystems, causing ecological imbalance and threatening global health (Rastogi et al., 2015). Blooms of cyanobacteria increase Biochemical Oxygen Demand over 5 days (BOD_5) and Chemical Oxygen Demand (permanganate method) (COD_{Mn}) levels, which means more organic substances – both dissolved and suspended – appear in the water, leading simultaneously to oxygen depletion. In addition, rising pH level can negatively affect the functioning of the aquatic ecosystem (Burdick et al., 2020; Zhang et al., 2022). Introducing effective and sustainable methods of surface water remediation can be key to restoring the ecological balance of aquatic ecosystems (Mazur et al., 2023; Zalewski, 2015). In the face of challenges such as cyanobacterial blooms in surface waters, every well-thought-out action aimed at improving water quality is important (Kibuye et al., 2021). Biological methods are generally cost-effective and sustainable but require long-term application (Liu et al., 2023; Pandey et al., 2009). In contrast, physical and chemical methods can rapidly remediate water bodies in the short-term. However, without a proper purification system, some chemical methods can easily lead to secondary pollution and residues (Sethi et al., 2025). In water and wastewater treatment, biological, physical, and chemical methods are used (Beklioglu et al., 2003; Mazur, 2020; Tomczyk et al., 2023). Some of these methods are also applied in the remediation of water bodies. An emerging approach that combines hydrotechnics and ecology is ecohydrology (Jurczak et al., 2019; Zalewski, 2015). Among biological methods, we can distinguish biomanipulation, effective microorganisms, and macrophyte management; among physical methods – adsorption and dredging; and among chemical methods – flocculation, ion exchange, and precipitation (Ahmad et al., 2025; Martinez and Hornbuckle, 2011). Although physical and biological remediation methods for water bodies offer valuable tools, chemical remediation remains essential due to its wide applicability, rapid response potential, and ability to alter chemical processes according to site-specific conditions (Sethi et al., 2025). In the remediation of small reservoirs or their separated sections, ion exchange using anion exchange resins may be applied. However, in practice, implementation can be challenging without the support of prior mechanical filtration that uses a gravel-sand or zeolite bed. Potential benefits of removing water pollutants can be achieved through process integration rather than relying on a single technology (Scott and Ollis, 1995). In small water bodies, the ion exchange method using anion exchange resins is more cost-effective than membrane processes (Gruss and Cyganowski, 2025). Unlike adsorption, this method leaves no compounds or materials – such as bentonite – in the water (Gruss et al., 2024), although adsorption is a cheaper option (Ahmad et al., 2025). Preliminary studies using ion-exchange resins yielded good results in the WOPR bay (Buta et al., 2022). In surface waters, however, this method remains poorly studied. The aim of this study is to determine whether a system combining sand-gravel filtration bed with ion exchange resins reduces the concentration of nitrate nitrogen (NO_3-N) and changes the organic matter content and the pH of the water separated by a fin boom in a reservoir. It is hypothesized that combining mechanical filtration with anion exchange will reduce the amount of organic matter and improve the pH of the water.

MATERIALS AND METHODS

Study area and the tested modular installation

The study was conducted at the large, multifunctional Turawa reservoir, on the peninsula at the Kemping and Marina Ventura resort (50º44’26” N, 18º06’01”). The Turawa reservoir is located on the Mała Panew river, which belongs to the upper Oder river basin in southern Poland, Europe. The subject of the study is a modular installation designed for remove biogenic compounds from water, located in a separated section of the water reservoir, isolated by means of a fin boom. (Fig. 1A). This installation employs ion-exchange technology using ion-exchange resins (a chemical water treatment method). When selecting the study site, it was decided to test the installation under field conditions in a eutrophic reservoir. The Turawa reservoir serves as such an example (Steinhoff-Wrześniewska et al., 2024; Wiatkowski and Wiatkowska, 2019). Additionally, the northern shore of the reservoir features separated

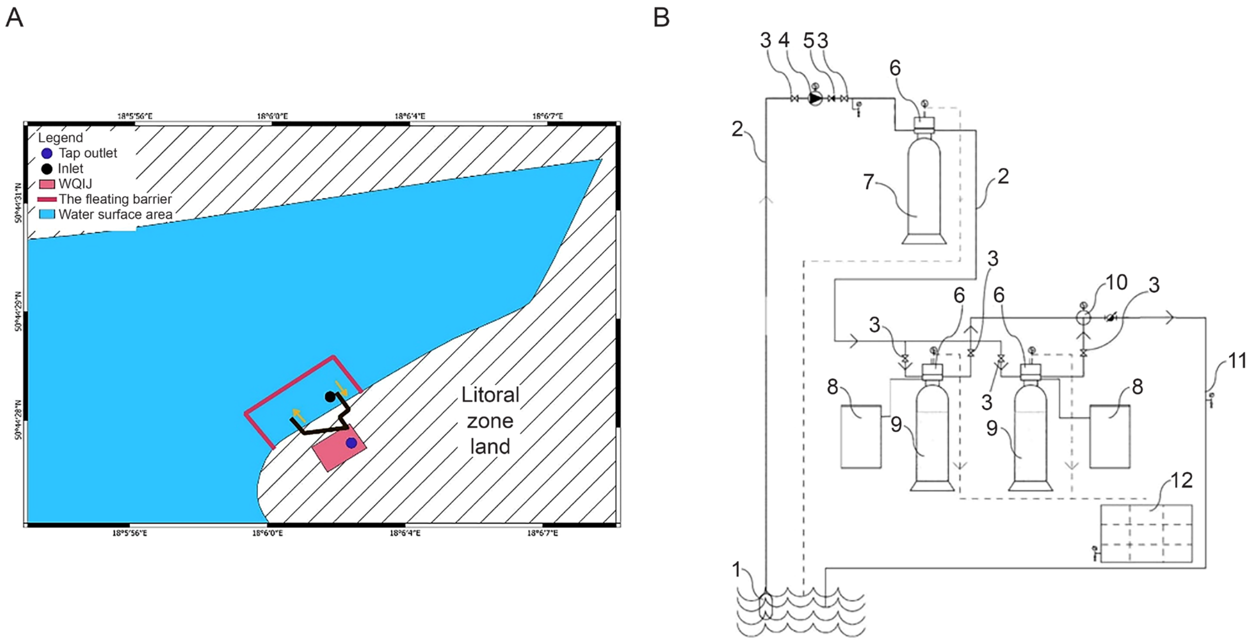

Fig. 1A. Location of the study site and **B.** general diagram of the WQII (Source: Authors' own elaboration)

areas formed by peninsulas near several recreational centers, which provide favorable conditions for the growth and blooming of cyanobacteria. Studies conducted in 2020–2021 showed that algal blooms in the Turawa reservoir were caused by two species of cyanobacteria: Microcystis wesenbergii (Komárek ex. Komárek, dominant species) i Microcystis aeruginosa Kützing (subdominant species). Green algae, diatoms, and euglenoids are also commonly present in the phytoplankton community (Gruss et al., 2024). This plankton limits the reservoir's suitability for its intended purposes (recreation, fishing, and supplying cooling water to a thermal power plant) (Gruss et al., 2024). An additional threat is the inflow of organic matter into the Oder river, which may lead to a decrease in dissolved oxygen concentration in the water.

The tested modular installation, hereinafter referred to as the Water Quality Improving Installation (WQII), is a four-module system with a capacity of $20\ m^3 \cdot h^{-1}$. Its general diagram was described in detail by Cyganowski et al. (2024). Each individual module has a capacity of $5\ m^3 \cdot h^{-1}$. The general schematic diagram shown in Fig. 1B refers to a single-module installation, indicating the following components: 1 – coarse impurity filter, 2 – contaminated water pipeline, 3 – shut-off valve, 4 – feed pump, 5 – check valve, 6 – control head, 7 – mechanical filtration column, 8 – reagent storage tank, 9 – ion-exchange filtration column, 10 – three-way valve, 11 – treated water pipeline, 12 – post-regeneration tank.

Raw water is taken directly from the surface water reservoir at the water intake point of the installation (Fig. 1A, Inlet) and passes through the coarse impurity filter (1) (Fig. 1B). The filter consists of a metal filter (Ø 50 mm) housed inside a perforated protective pipe (Ø 200 mm) covered with drilling filter mesh. Water circulation in the installation is forced by the operation of the feed pump (4). The feed pump (4) is an electric pump powered by a 230 V outlet and connected on one side via a shut-off valve (3) to the coarse impurity filter (1) through the contaminated water pipeline (2), and on the other side, through another shut-off valve (3) and a check valve (5), to the sand-gravel bed column (7). The pump's operation is initiated and controlled by a frequency inverter. Directly behind the shut-off valve (3) on the outlet side of the pump (4), a pressure sensor and a pressure compensation tank are installed. The pump is protected against dry running. In the event of pump shutdown, the check valve (5) prevents the gravitational drainage of the installation and the uncontrolled backflow of water into the reservoir. Filtration is carried out through a series-connected system consisting of a mechanical filtration column (7) and two ion-exchange filtration columns (9), which operate in a twin configuration (alternating operation of the columns) and are interconnected via a three-way valve (10). Each ion-exchange column has a capacity of 200 liters. The alternating sequence of filtration and backwashing (regeneration) of the sand-gravel bed in the mechanical filtration column (7) is controlled by the control head (6), powered by a 230 V outlet. The post-regeneration discharge is directed back into the reservoir (containing only water from the reservoir and solid impurities trapped during filtration). Shut-off valves (3) are installed on both the inlet and outlet sides of the mechanical filtration column (7). The filtration medium in both ion-exchange columns (9) is Pure Resin PA 202 ion-exchange resin, characterized by the following parameters: particle size range: +1.2 mm < 5%, −0.3 mm < 1%; water retention, Cl^- form: 52–56%; shipping weight: 680–730 g/L; total ion-exchange capacity: 1.0 eq/L (Pure Resin Co. Ltd., 2022). The resin is a strongly basic anion exchange resin based on a styrene–divinylbenzene matrix, supplied in a swollen hydrochloride form. It is suitable for operation over a wide pH range (1–14) (Pure Resin Co. Ltd., 2022; Cyganowski et al., 2024) and exhibits good chemical stability, enabling the removal of chemical contaminants from aqueous solutions (Ahmer and Uddin, 2024; Ren et al., 2016). The resin exhibits ion-exchange efficiency, enabling removal of dissolved ionic species during column operation (Cyganowski et al., 2024). The resin was not replaced during the entire study period.

All columns (7 and 9) are interconnected with contaminated water pipelines (2). The operation of the ion-exchange columns (9) is controlled by control heads (6). Shut-off valves (3) are installed on both the inlet and outlet sides of each ion-exchange column (9). The treated water is discharged through the treated water pipeline (11) directly back into the water reservoir (Fig. 1B). The pipeline outlet is indicated by a yellow arrow extending from the installation (Fig. 1A). However, for sampling purposes, water was drawn from this point using a faucet (not shown in the diagram) (Fig. 1B). The regeneration process of the ion-exchange resin uses calcium chloride, stored in reagent tanks (8) connected to each ion-exchange column (9). The eluate is collected through a separate pipeline system and discharged via the eluate line into an external post-regeneration tank (12). The twin configuration of the ion-exchange columns (9) allows continuous 24-hour operation. Thus, filtration and regeneration processes occur in alternating cycles. After the completion of both mechanical and ion-exchange filtration, the treated water exiting the ion-exchange resin column (9) is discharged directly back into the surface water reservoir from which the raw water was originally drawn (Skorulski et al., 2024). The working exchange capacity was reported in the studies by Cyganowski et al. (2024) and Gruss and Cyganowski (2025).

Sample collection and physico-chemical analysis

Water sampling and measurements were conducted between May and November 2020–2021. Water sample collection dates: 11.05.2020, 15.06.2020, 23.06.2020, 24.07.2020, 30.08.2020, 17.11.2020, 23.03.2021, 24.05.2021, 21.08.2021, 30.08.2021, 11.10.2021, 04.11.2021, 29.11.2021. Samples were collected randomly. If the water depth exceeded 1 m, sampling was performed using a 1.7 L Ruttner KC-Denmark sampler. For shallower depths, samples were taken from the subsurface water layer. Samples were stored at 4°C and analyzed on the same day of collection. The calculated residence time of water in the WQII, from inlet to outlet, is 5 minutes and 50 seconds. A water sample was collected from tap valve after this period. Water pH was measured in situ using a YSI EXO2 multiparameter probe. For BOD_5 analysis, water was collected in 300 mL glass bottles with ground-glass stoppers. For COD_{Mn} and NO_3-N analyses, water was collected in 1.5 L polypropylene bottles with screw caps. Ex situ analyses of BOD_5, COD_{Mn}, and NO_3-N were performed at the Environmental Research Laboratory of the Institute of Environmental Engineering, Wrocław University of Environmental and Life Sciences, according to PN-EN and ISO standards. Specifically: BOD_5: PN-EN 1899-1:2002 (limit of quantification: 0.5 mg · L^{-1}; detection limit: 0.1 mg · L^{-1}), COD_{Mn}: PN-EN ISO 8467:2001 (limit of quantification: 0.5 mg · L^{-1}; detection limit: 0.2 mg · L^{-1}), NO_3-N: spectrophotometric method according to PN-82C-04576/08 (limit of quantification:

0.05 mg · L^{-1}; detection limit: 0.007 mg · L^{-1}). Three replicates were performed in each campaign, and the mean value of BOD_5,COD_{Mn}, NO_3-N was calculated. For pH, the median value was used. Instruments used are included in Buta et al. (2023) and Gruss et al. (2021).

Statistical analysis

The values of the analyzed water quality indicators (pH, BOD_5, COD_{Mn}, and NO_3-N) were arranged according to the measurement dates, and the normality of each variable was tested using the Shapiro–Wilk test. Subsequently, histograms (not published) were created to assess which distribution best fitted the data and could be applied in the Generalized Linear Model (GLM). The effect of WQII on the concentration of each compound was examined using the GLM: Indicator ~ Site. Four separate GLMs were fitted – one for each water quality indicator. The indicators pH, BOD_5, COD_{Mn}, and NO_3-N were treated as response variables, while Side (tap outlet or pipeline inlet) served as an explanatory variable. Site was treated as a categorical variable. Additionally, to enable temporal forecasting from May to November, the Indicator ~ Site + Date forms of GLMs were developed. This was done to verify whether including time improved model fit, suggesting that changes in the indicator might be associated with the passage of time and could reflect a persistent trend of effective water pollution reduction. The best model was selected based on the Akaike information criterion (AIC), and the significance of the independent variable was assessed using Type III Wald χ^2 tests with the ANOVA function from the car package (ver. 3.1–3) in R (de Caralt et al., 2020). After fitting the GLM, the uncertainty of the regression coefficient corresponding to the tap outlet level of the variable Site, as well as its 95% confidence interval, was estimated using the bootstrap method (1,000 iterations) (Noda et al., 2022) implemented in the boot package (ver. 1.3–32). For each resample, the value of the tap outlet coefficient was recorded, and bootstrap was applied only for the coefficient for which tap outlet had a p-value < 0.05. The measurements performed during a single operating cycle were presented as a function of the remaining sorption capacity of the bed volume (V), as read at the time of sample collection (Fig. 5). Data were analyzed in Origin Pro v. 2022 and R v 4.5.1 (R Core Team, 2025; Origin Pro, 2022).

RESULTS

To assess the impact of the variable Side (pipeline inlet vs. tap outlet) on water quality parameters, GLM with a Gamma distribution were applied, as the values were positive and skewed, which was evaluated based on a histogram (not published). For the dependent variables (NO_3-N, BOD_5, COD_{Mn}), a log link function was used, whereas for pH, an identity link was applied, allowing direct interpretation of differences in measurement units.

The GLM for NO_3-N (AIC = 28.16) showed a significant influence of the Side factor on the NO_3-N concentration ($\beta = -0.99$, df = 24, SE = 0.36, t = –2.72, p = 0.012). NO_3-N levels at the tap outlet were significantly lower than at the pipeline inlet, with the estimated effect corresponding to an approximately 63% decrease in mean values. The bootstrap 95% confidence interval (–1.84, –0.35) confirms the robustness of this effect. This indicates a marked reduction of NO_3-N at the tap outlet, suggesting the occurrence of nitrate-reducing processes in the examined section or in the water transport system. For the other analyzed parameters (pH, BOD_5, and COD_{Mn}), no statistically significant effect of Side was observed; however, a favorable trend of lower values at the tap outlet was noted. For pH (AIC = 50.22), values were slightly lower at the tap outlet ($\beta = -0.13$, df = 24, SE = 0.23, p = 0.58), which may suggest a minor decrease in alkalinity of 0.13 pH units at the tap outlet. A similar positive tendency was observed for organic matter indicators – BOD_5 ($\beta = -0.16$, SE = 0.17, p = 0.35) and COD_{Mn} ($\beta = -0.24$, SE = 0.35, p = 0.49), with AIC values of 110 and 178, respectively. Mean values were also lower by 15.4% (BOD_5) and 21.4% (COD_{Mn}) at the tap outlet, indicating a potentially reduced organic load in water leaving the WQII installation.

The GLM results for NO_3-N, pH, BOD_5, and COD_{Mn} are consistent with the observed data distributions presented in the boxplots and temporal distribution plots (Fig. 2A–H). The distribution of NO_3-N concentrations shown in the boxplots suggests lower values at the tap outlet compared to the pipeline inlet (Fig. 2A). Similarly, Fig. 1B indicates

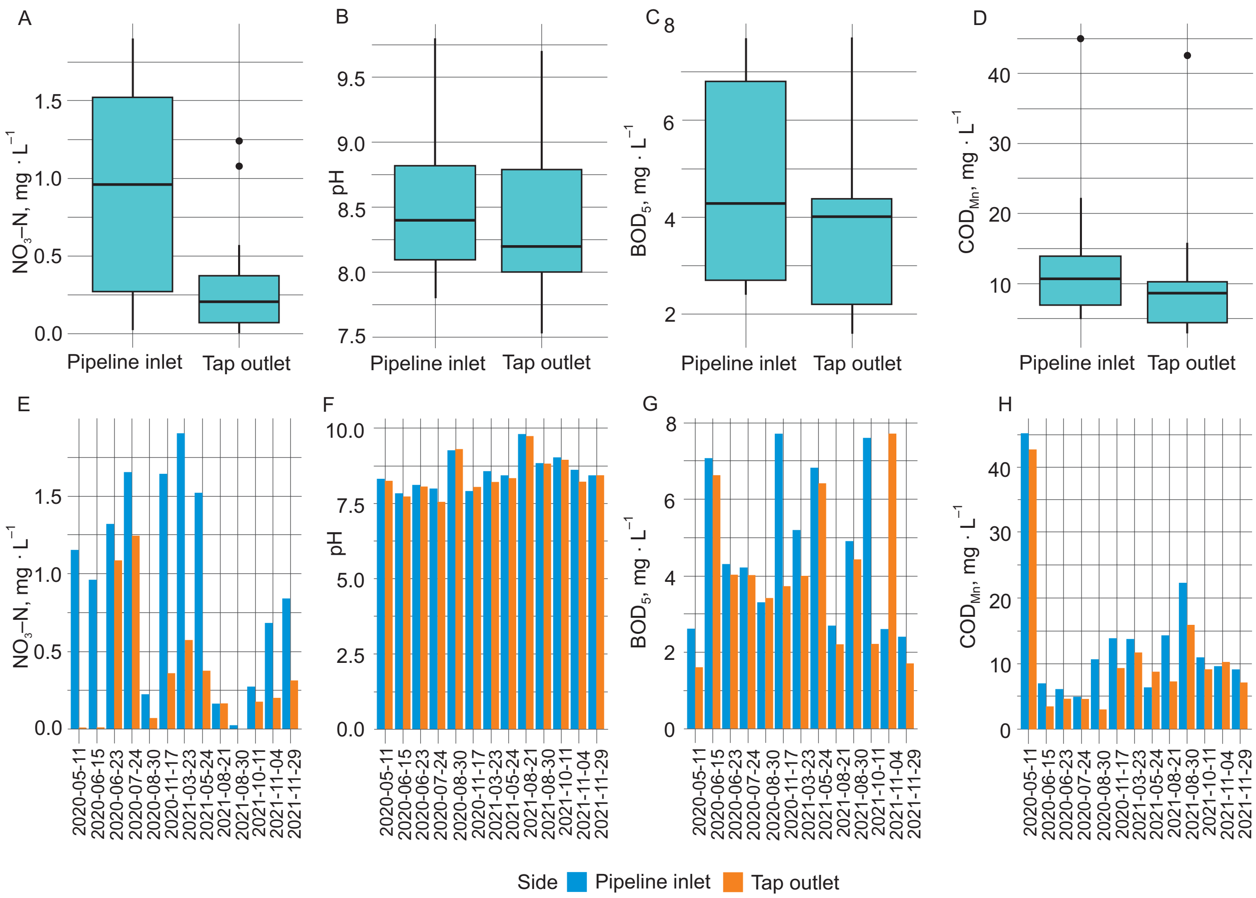

Fig. 2. Boxplots (**A–D**) and temporal distributions (**E–H**) illustrate the changes in NO_3-N, pH, BOD_5, and COD_{Mn} values between the pipeline inlet and tap outlet. In the temporal distributions (**E–H**), each parameter was analyzed in triplicate, and the mean value was calculated. For pH, the median value was used (Source: Authors' own elaboration)

a slight shift toward lower pH values at the tap outlet. Lower median values of BZT_5 and $ChZT_{Mn}$ were also observed at the tap outlet compared to the pipeline inlet (Fig. 2C–2D). Mean NO_3-N concentrations at the pipeline inlet varied throughout the study period. The lowest value was recorded on August 30, 2020, while the highest occurred on March 23, 2021. Maximum reduction effectiveness was observed on August 30, 2021, and the minimum on June 24, 2020 (Fig. 2E). Overall, a comparison between the pipeline inlet and the tap outlet demonstrates that, in most cases, pH, BOD_5, and COD_{Mn} values were lower at the tap outlet (Fig. 2E–H).

Based on the GLMs, predicted values of water quality indicators (NO_3-N, pH, BOD_5, and COD_{Mn}) were generated with 95% confidence intervals for the period from May to November, for two locations: the pipeline inlet to the WQII and the tap outlet of the WQII (Fig. 3A–D). The NO_3-N concentrations as well as COD_{Mn} and to a lesser extent BOD_5 are consistently lower at the tap outlet than at the pipeline inlet. A clear decrease in NO_3-N and COD_{Mn} from May to November is observed at both locations, while BOD_5 shows only a slight downward trend. In contrast, projected pH values increase over time, at both the inlet and the outlet. Overall, the values of the water quality indicator remain higher at the pipeline inlet compared to the tap outlet throughout the study period (Fig. 3A–D). The model is limited by the lack of seasonal variation analysis, although the forecasts suggest that seasons have an influence on BOD_5, COD_{Mn}, and NO_3-N (Fig. 3B–D).

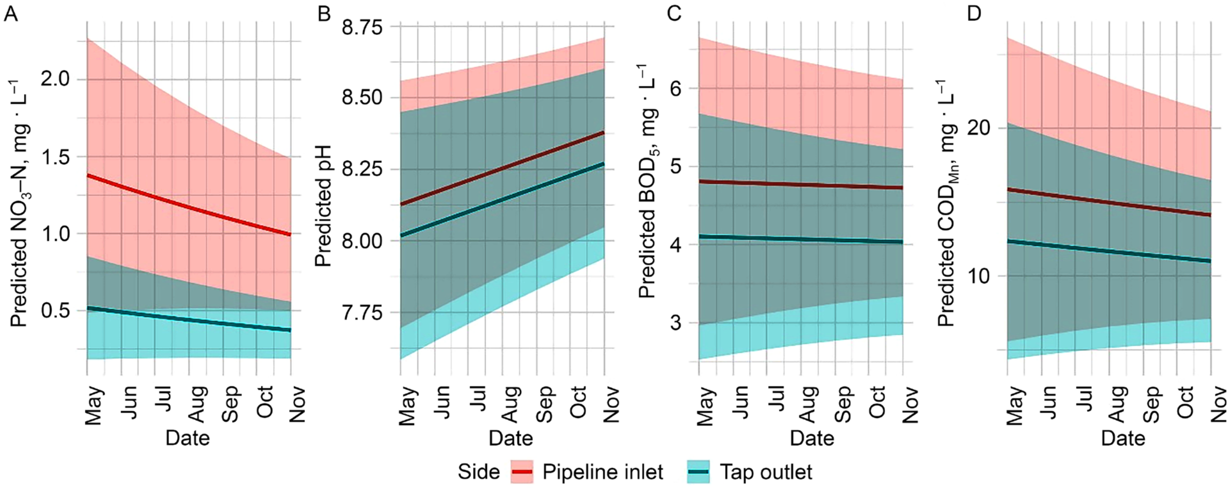

Fig. 3. Predicted **A.** NO_3-N concentration, **B.** pH, **C.** BOD_5 concentration, **D.** COD_{Mn} concentration (May–November) with 95% Confidence Interval (Source: Authors' own elaboration)

During the analyzed period, several test series were conducted to compare the efficiency of NO_3-N reduction in water collected directly from the WQII tap outlet versus water collected from the post-treatment reservoir near the WQII outlet. The results showed that the efficiency of NO_3-N reduction was significantly higher in water collected at the tap outlet (Fig. 4). For samples taken from the tap, the median reduction efficiency was approximately 70%, with an interquartile range of 40% to 78%, and maximum values reaching 99.7%. For samples collected from the post-treatment reservoir (near outlet WQII), the median was much lower at 39.4%, with an interquartile range of 28.8 to 66.7% and a maximum value of 96.6% (Fig. 4). This large difference in efficiency indicates that the treatment process is not fully isolated. Partial mixing of water within the tank is possible, and it can "dilute" the purification effect despite the partial separation of water in the bay using a fin boom.

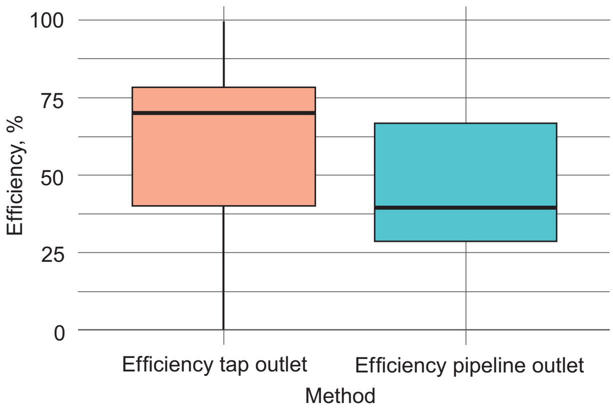

Fig. 4. Comparison of efficiency of the NO3-N reduction: tap outlet vs pipeline outlet (Source: Authors' own elaboration)

Additionally, beyond the previously described analyses, the removal of NO_3-N during a single operating cycle of the WQII was evaluated as a function of the volume of treated water (Fig. 5). The horizontal axis represents the remaining treated water volume until the end of the cycle, starting from 160 and decreasing to 0, as the available sorption capacity was exhausted, while the NO_3-N concentrations measured at the inlet and at the tap outlet are shown on the right vertical axes (blue and red, respectively). The left vertical axis represents the percentage removal of NO_3-N. The NO_3-N concentrations at the inlet to the installation ranged from approximately 2.5 to 3.7 $mg \cdot L^{-1}$ and showed moderate variability across the treated water volumes. Concentrations measured at the tap outlet were consistently lower, ranging from approximately 1.2 to 2.6 $mg \cdot L^{-1}$. The NO_3-N removal efficiency varied from about 15% to nearly 68% over the operating cycle. Higher removal efficiencies were observed at larger capacity volumes (approximately 130–150 m^3), while lower efficiencies were recorded at smaller volumes, particularly below approximately 60 m^3 (Fig 5).

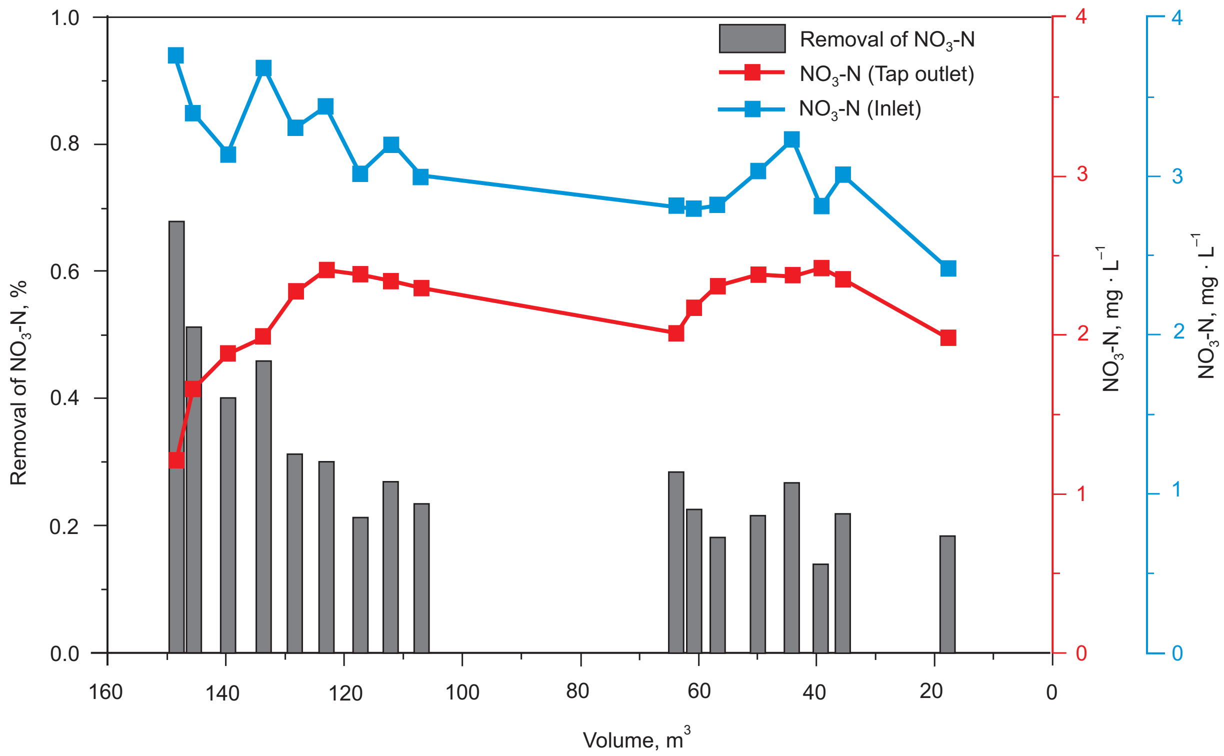

Fig. 5. Removal of NO_3-N in a single operating cycle of the WQII (Source: Authors' own elaboration)

DISCUSSION

The analysis revealed a reduction in the NO_3-N concentrations, which is consistent with numerous studies on strongly basic ion-exchange resins (Al-Agili, 2021; Magette et al., 1990; Nujic et al., 2017; Samatya et al., 2006). However, the cited studies mainly focus on treated groundwater or laboratory experiments. It should be noted that the NO_3-N levels removed from the reservoir water are generally much lower than those in the cited studies (Nujic et al., 2017; Samatya et al., 2006). There is limited research on the use of anion-exchange resins for the remediation in a separated section of the water reservoir (Buta et al., 2022; Cyganowski et al., 2024; Liu et al., 2021). In the present study, the efficiency of NO_3-N reduction in treated water varies over time. It primarily depends on how close the process is to the breakthrough point (Fig 5). The earlier the breakthrough point, the more effective the purification. In the studied installation, the twin system allows the second column filled with ion-exchange resin to start treatment when the first column reaches breakthrough, while the first column undergoes resin regeneration (Cyganowski et al., 2024; Gruss et al., 2024). The observed pH decrease in water (Fig. 2F) is caused by the sand-gravel filter, as confirmed by previous studies (Xi et al., 2005; Rooklidge and Ketchum, 2002; Tan et al., 2013), and by analyses using combined sand-gravel and activated carbon filters (Xi et al., 2005; Tan et al., 2013). Fine particles, including some organic matter (e.g., organic nitrogen) and ammonium nitrogen, are retained in the sand-gravel filter. These compounds are subsequently removed during backwashing as effluent (Gruss and Cyganowski, 2025), which leads to a decrease in water pH. Although the negative beta coefficient in the GLM confirms reductions in BOD_5 and COD_{Mn}, there are series in which the concentrations of these parameters were not always lower after water passed through the WQII (for BOD_5, 2 of 13 series: 30.08.2020, 04.11.2020; for COD_{Mn}, 2 of 13 series: 24.05.2021, 04.11.2021). To explain this, the sand-gravel filter treatment mechanism must be examined in detail. This treatment mechanism is based on particle deposition in micropores, surface sorption, and sifting through the filter layers (Villabona-Ortíz et al., 2022). The filter retains colloids and mineral and organic suspensions (Hamidah et al., 2022; Xi et al., 2005; Tan et al., 2013; Villabona-Ortíz et al., 2022). Easily biodegradable organic matter contributes to BOD_5 (Hamidah et al., 2022; Smyk et al., 2015), whereas some organic fractions consist of dissolved or suspended matter that is non-biodegradable or degrades slowly, contributing to COD_{Mn} (Smyk et al., 2015). When the easily biodegradable fraction is removed by the filter media, BOD_5 decreases after water passes through the WQII, while the fraction of that degrades more slowly remains in the media, especially when retention times are short (Xi et al., 2005). Furthermore, if samples were taken at different times relative to the backwashing cycle, retained material may be partially released during flow reversal, affecting subsequent measurements. The obtained results support the hypothesis that combining mechanical filtration with anion exchange contributes to reducing organic matter content and improving water pH. Removing some organic matter may increase the dissolved oxygen concentrations in the reservoir water (Mazur et al., 2023). This can be achieved by redirecting the backwash effluent from the gravel-sand filter to a separate effluent tank and using it as organo-mineral fertilizer (Malovanyy et al., 2021). Consequently, the ecosystem stabilizes, as a lower number of algae reduces the amount of biomass subject to decomposition after their death (Tammeorg et al., 2024; Yin et al., 2025).

Predicted trends indicate persistent differences in water quality between pre- and post-treatment water, suggesting the effectiveness of the treatment process in reducing contaminants.

The results also indicate that the NO_3-N reduction was significantly higher in samples taken directly from the WQII tap, as the purification process is most effective at the point of system operation. Lower values in reservoir samples may result from the partial mixing of treated and untreated water. The removal of nitrogen and some of the organic matter limits the availability of nutrients for algae and reduces oxygen consumption in the water. This inhibits eutrophication and improves the ecosystem quality in the treated portion of the reservoir.

CONCLUSSION

The analysis showed that the Water Quality Improving Installation effectively reduces NO_3-N concentrations, confirming the efficiency of the anion exchange resin used under surface water conditions. The installation is most effective immediately after purification in the ion-exchange column. The decrease observed in the reservoir water likely results from partial mixing of treated and untreated water. The variability in the efficiency of NO_3-N reduction over time is related to the operating and regeneration cycle of the ion--exchange bed, indicating alternating operation of the columns. The Water Quality Improving Installation also contributes to reducing organic matter concentrations and improving water pH. Removing some of the organic matter and nitrogen compounds may reduce oxygen consumption in the water and affect the availability of nutrients for phytoplankton. This supports the maintenance of the oxygen balance and improves the ecological quality of the isolated part of the reservoir.

CRediT author contribution statement

Conceptualization, MW, LG; methodology, LG, BB; software, LG, BB; validation, LG, MW; formal analysis, BB; investigation, LG, BB; resources, BB, LG; data curation, BB, LG; writing–original draft preparation, BB, LG; writing–review and editing, LG, BB; visualization, LG; supervision, MW; project administration, MW; funding acquisition, MW. All authors read and approved the final manuscript.

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OBNIŻENIE ZAWARTOŚCI AZOTU AZOTANOWEGO I MATERII ORGANICZNEJ W ZBIORNIKU WODNYM ODIZOLOWANYM ZA POMOCĄ PŁYWAJĄCEJ BARIERY PRZY UŻYCIU FILTRA PIASKOWO--ŻWIROWEGO W POŁĄCZENIU Z ŻYWICAMI JONOWYMIENNYMI

ABSTRAKT

Cel badań

Zakwity sinic powodują wzrost zawartości materii organicznej oraz wyższe stężenia biochemicznego zapotrzebowania na tlen w ciągu 5 dni (BOD_5) i chemicznego zapotrzebowania na tlen (metoda nadmanganianowa) (COD_{Mn}), jednocześnie prowadząc do wyczerpania tlenu. Ponadto rosnące poziomy pH mają szkodliwy wpływ na funkcjonowanie ekosystemu wodnego. Celem niniejszego badania była ocena skuteczności instalacji poprawiającej jakość wody (WQII) w redukcji stężeń azotu azotanowego (NO_3-N) oraz w zmianie zawartości materii organicznej i pH wody oddzielonej za pomocą bariery z płetw w zbiorniku retencyjnym.

Materiały i metody

Do analizy parametrów NO_3-N, BOD_5, COD_{Mn} oraz pH zastosowano uogólnione modele liniowe (GLM).

Wyniki i wnioski

Wyniki wykazały statystycznie istotny spadek poziomu NO_3-N przy wylocie z kranu w porównaniu z poziomem przy wlocie do rurociągu. W przypadku pozostałych parametrów (pH, BOD_5, COD_{Mn}) nie zaobserwowano statystycznie istotnych różnic, choć odnotowano pozytywną tendencję spadkową wartości przy wylocie z instalacji. Pomiary skuteczności redukcji NO_3-N wskazały na znacznie wyższą skuteczność w wodzie pobranej bezpośrednio z kranu instalacji (mediana 70%) w porównaniu z próbkami z zbiornika (mediana 39,4%), co sugeruje, że woda w zbiorniku jest częściowo wymieszana. Redukcja NO_3-N i materii organicznej ogranicza dostępność składników odżywczych dla fitoplanktonu i obniża zużycie tlenu, przyczyniając się do stabilizacji ekosystemu i poprawy jakości ekologicznej badanego zbiornika. Wyniki potwierdzają skuteczność zastosowanej instalacji w poprawie parametrów jakości wody i zmniejszeniu ryzyka eutrofizacji.

Słowa kluczowe: wymiana jonowa, zbiornik wodny, zapora płetwowa, rekultywacja, eutrofizacja