JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2024, 25(3), 182–194
https://doi.org/10.12911/22998993/177926
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.12.24
Accepted: 2024.01.07
Published: 2024.01.24

Changes in Physicochemical Indicators of Water Resulting from River Activities – Case Study in Nida Valley, Poland

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ABSTRACT

Stara Nida represents one of the three hydrological channels traversing the Nadnidziański Landscape Park, a locale characterized by ecological diversity within the Nida valley, Poland. Historically rendered inactive due to flow regulation, this specific river branch underwent restoration in February 2023 as a pivotal component of the "Restoration of the Inland Delta of the Nida River" project. The revitalization of Stara Nida has precipitated beneficial ecological metamorphoses within the landscape. To evaluate the impact of the restoration of the Stara Nida branch on the physicochemical characteristics of water in the landscape, systematic sampling of regional SW and GW was conducted. The sampling duration covered a 12-month period, segmented into two phases: the first six months leading up to the restoration (from February 2022 to July 2022) and the subsequent six months following the restoration of the Stara Nida branch (from February 2023 to July 2023). A total of 114 water samples were collected from 10 distinct sampling locations. In-situ measurements of key indicators, including temperature (T), electrical conductivity (EC), dissolved oxygen (DO), pH, and total dissolved solids (TDS), were performed using handheld devices. Concurrently, laboratory analyses were carried out for total nitrogen (TN), total phosphorus (TP), chloride (Cl^-), sulfate (SO_4^{2-}), manganese (Mn^{2+}), iron ($Fe^{2+,3+}$), zinc (Zn^{2+}), cadmium (Cd^{2+}), lead (Pb^{2+}), copper (Cu^{2+}), and chemical oxygen demand (COD). Statistical analyses encompassed the Shapiro-Wilk test ($\alpha = 0.05$) and the Wilcoxon (Mann-Whitney) rank sum test ($\alpha = 0.05$) to discern significant disparities in physicochemical indicators at sampling points pre- and post-restoration of the Stara Nida branch. Additionally, Pearson correlation analysis ($\alpha = 0.001$) was employed to evaluate overarching changes at the sampling points attributable to the impact of the Stara Nida branch restoration.

Keywords: Nida Valley, physicochemical indicators, restoration, statistical method, environmental monitoring method.

INTRODUCTION

In the natural environment, water is commonly categorized into two primary types: surface water (SW), which covers a significant portion of the Earth's surface, and groundwater (GW), found beneath the ground surface. While these two water sources are often examined independently, it is essential to recognize the inherent interactivity between them. In reality, there is a dynamic relationship that influences the properties of water in both surface and subsurface areas (Findlay, 1995; Kowalik et al., 2015; Phan et al., 2023a). The classification of water sources relies on criteria related to both quality and quantity. Water quality is gauged through its physical and chemical indicators, typically assessed prior to its utilization. Alterations in water composition can stem from natural processes and human activities. Natural factors involve rock weathering processes that introduce minerals into water, while human activities encompass urbanization, agricultural development, flow regulation, and waste discharge (Amadi et al., 2010; Bogdał et al., 2016; Voudouris et al., 2018)

Natural variations in water are a consequence of shifts in hydrometeorological factors, along with topographic and hydrogeological features

(Hendricks and White, 1991; Rinderer et al., 2014; Giese et al., 2020). In cold humid climates, a predominant hydrometeorological characteristic is substantial winter precipitation. Water will accumulate in ice during freezing temperatures and be released when warmer (Kovalevskii, 2007; Jasechko et al., 2017). The main annual additions to water sources are from glacial meltwater and enhanced precipitation (Clilverd et al., 2011; Meixner et al., 2016). In less human-impacted natural landscape areas, alterations in water composition are primarily attributed to specific soil properties, natural conditions of the soil, and regional watercourses (Valett et al., 1990; Kirkinen et al., 2005). The objective of this research is to study variations of the physicochemical indicators of SW and GW before and after the restoration of the Stara Nida (SN) branch in the research area. Subsequently, the research aims to assess the impact of the flow restoration process on both GW and SW in the designated area.

To clarify the objective of this study, an environmental monitoring methodology was implemented to evaluate alterations in physicochemical indicators of water. The GW indicators were ascertained through the collection of GW samples obtained from strategically positioned monitoring wells. To enhance the reliability of results, these monitoring wells were systematically arranged horizontally close to the observation points. The utilization of multiple monitoring points facilitated a comprehensive depiction of physicochemical properties (Borden et al., 1997; Conant et al., 2004). The establishment of an expansive system of monitoring points was undertaken to provide for accurate information concerning the spatial dispersion of these components.

Conversely, for SW, the determination of physicochemical indicators involved the analysis of water samples acquired from diverse sources, including grab or bottle samples. However, it is imperative to note the inherent limitations of this method, because it only records the value at a certain time during the sampling process. Furthermore, when the substance content is in trace form, a substantial volume of water sample is necessitated (Pitkin et al., 1999; Vrana et al., 2005). These questions are surmounted by automated monitoring points were deployed to enable continuous monitoring over an extended duration. This approach was instrumental in addressing the limitations associated with discrete sampling methodologies and provided a more comprehensive understanding of temporal variations in water physicochemical indicators.

MATERIALS AND METHODS

Research area

The research area is located within the Nida Valley, situated in Poland. The Nida Valley covers a natural area of 3,862.8 square kilometers and is distinguished by expansive plains, verdant grasslands, and waterlogged forests. The typical soil composition in this region comprises a sand layer overlaid by a thin mud mantle. The shape of the Nida Valley can be attributed to the meandering flow of the Nida River (NR). Within this valley, three primary waterways exist. The central watercourse is the NR itself, spanning a length of 151.2 kilometers. The remaining two branches are the Smuga Umianowicka (SU) branch and the Stara Nida (SN) branch.

The flow of the NR has undergone multiple alterations due to flow regulation measures. In certain sections, the flow of river has been intentionally shortened. Starting from the 1960s and extending into the initial decades of the 20th century, efforts were made to regulate the flow of the NR, resulting in a reduction in its length. The original course of the river, known as SN, was gradually shifted to the left, ultimately forming the NR as we know it today. However, downstream sections of the river still keep the original course. Accordingly, the flow of the SN branch had been interrupted in the study area for an extended period until it was successfully reinstated in February 2023 through the “Restoration of the Inland Delta of the Nida River” project. The revitalized branches now play a vital role in sustaining a consistent flow within the area during the period under investigation.

The specific study area is situated within the Nadnidziański Landscape Park and is an integral part of a important ecological region (Strużyński et al., 2015). This research site surrounds the territory located from the NR to the SU branch, as illustrated in Figure 1. The floodplain within the Landscape Park is subject to seasonal inundation, with regular spring flooding and occasional winter flooding, stay for a period of many months annually. The floodplain widens significantly, spanning many square kilometers. This floodplain serves as a vital natural reservoir, reducing the flooding hazard of riverside area (Łajczak, 2004; Borek and Drymajło, 2019).

Sampling points

Ten meticulously selected sampling points were established within the Nadnidziański Landscape Park, with seven points specifically indicated as sampling locations of GW (GW1 to GW7). These GW sampling points are drilled wells with a depth of 2 meters and a diameter of 10 centimeter. The distance between wells is from 150 to 200 m and extends in a straight horizontal line. These wells are fixed with plastic pipes and have covers to prevent surface water from entering from above. Additionally, three SW sampling locations were strategically positioned within the watercourse. At the NR is SW1, at the SN branch is SW2, and SW3 at the SU branch. The sampling range spanned 1365 meters extending from the NR to the end of the flood plain area (refer to Figure 1).

Sample collection

A comprehensive set of 114 water samples was gathered over a 12-month period (phase 1 from February 2022 to July 2022 and phase 2 from February 2023 to July 2023). This collection included 84 GW samples and 30 SW samples, obtained from a total of 10 sampling points. These points comprised 7 locations for GW sample collection and 3 locations for SW sample collection. The sampling effort spanned 6 months before and 6 months after the restoration of the SN branch. Specifically, for SW samples at the SN branch, sampling occurred exclusively in the 6 months following its reinstatement, from February 2023 to July 2023. Water samples were collected monthly. The collection process involved the use of a sampler equipped as vertical tube, and the water was stored in plastic bottles of 300 cm³. Immediate transportation to the experimental facility took place on the collection day. The samples were keeped in a icebox at 4°C to preserve their integrity.

Field measurement

Physical indicators were determined right at the sample collection points using handheld devices. Oxygen meter (CO-411) was utilized for temperature (T) and dissolved oxygen (DO) measurements, while electrical conductivity (EC) was measured by conductivity meter (CC-102), pH was measured by pH meter (CP-104), and dissolved substances meter (TDS-3) was used for total dissolved solids (TDS) measurement. To ensure the accuracy of the readings, the devices

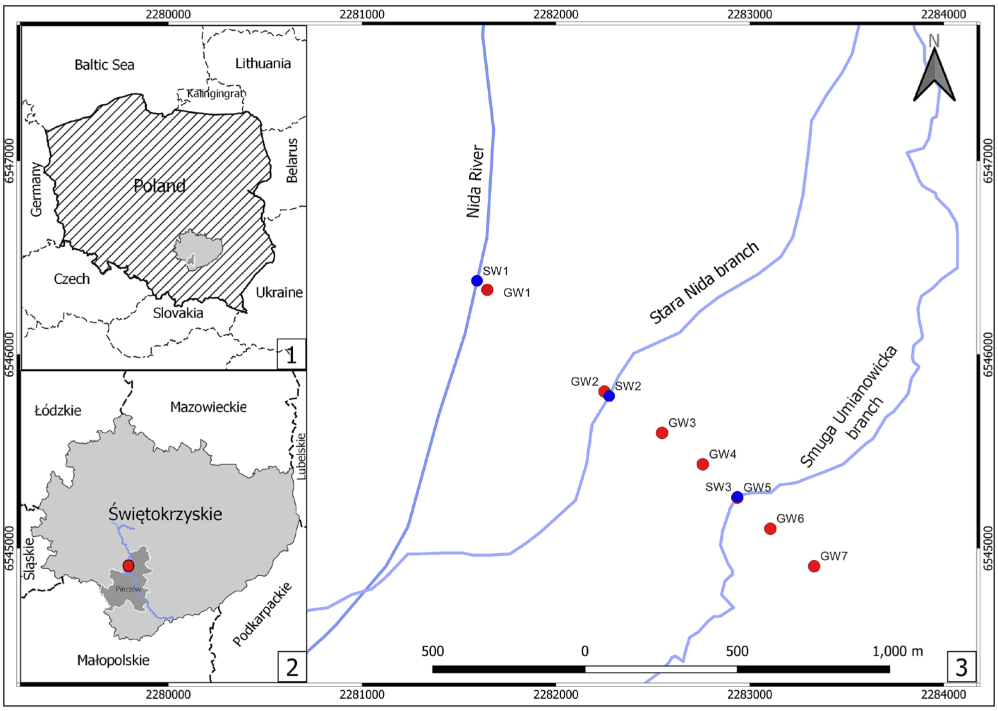

Fig. 1. Map of study area and sampling sites in the Nida valley, explanation: red points - groundwater collected locations; blue points – water surface collected locations

were calibrated in accordance with the manufacturer's recommendations.

Laboratory analysis

Chemical indicators were analysed using the American Public Health Association (APHA 1998) and the Environmental Protection Agency (EPA 1983) methods in the laboratory. Quantities of total nitrogen (TN) and total phosphorus (TP) were measured through the FiaCompact MLE flow analyser with mineralizer. The amount of $Fe^{2+,3+}$, Zn^{2+}, and Mn^{2+} was determined using the atomic absorption spectrometry (AAS) method with the Unicam Solar spectrophotometer at wavelengths 248.3 nm for $Fe^{2+,3+}$, 249.5 nm for Zn^{2+} and 213.9 nm for Mn^{2+}. Cd^{2+}, Cu^{2+}, and Pb^{2+} were measured using the EcaFlow analyser through the colorimetric method. The content of Cl^{-} was determined using the FiaSTAR analyser through the flow analysis method, while SO_4^{2-} was measured by the turbidimetric method. The method of titration using potassium permanganate was exploited for chemical oxygen demand (COD) measurement. The detection limit (LOD) and quantitation limit (LOQ) of measurements are provided in Table 1.

Monitoring data and statistical analysis method

The Shapiro-Wilk test ($\alpha = 0.05$) was used to defind the normal distribution of the variables. To determine significant differences for each indicator before and after the restoration of the SN branch at various sampling points, the Wilcoxon test at $\alpha = 0.05$ was executed. Additionally, the dataset of physicochemical indicators before and after the restoration of the SN branch at sampling points underwent analysis through the calculation of Pearson's correlation. The correlation matrix was created by determining coefficients for sampling points before and after the restoration of the SN branch. Significance in correlation was decided through the r-value and a significance level (p) of 0.001. Meteorological monitoring data include precipitation and temperature were sourced from the Kielce-Suków monitoring station available at the website (https://hydro.imgw.pl). These data were utilized to investigate correlations between indicator changes and meteorological factors. Figure 2 illustrates variations in temperature and precipitation throughout the research period.

The statistical analysis has used the R program, free software under the GNU license. Results are presented as average values, standard deviation, minimum and maximum values, with the variation of physical and chemical indicators at sampling points.

Table 1. Limit of detection (LOD) and limit of quantitation (LOQ) for the indicators

Indicator	Measurement unit	*LOD*	*LOQ*
TN	$mg \cdot dm^{-3}$	0.05	0.05
TP	$mg \cdot dm^{-3}$	0.005	0.01
Cu^{2+}	$\mu g \cdot dm^{-3}$	0.5	1.00
Pb^{2+}	$\mu g \cdot dm^{-3}$	0.5	1.00
Cd^{2+}	$\mu g \cdot dm^{-3}$	0.5	1.00
Cl^{-}	$mg \cdot dm^{-3}$	0.1	1.00
$Fe^{2+,3+}$	$mg \cdot dm^{-3}$	0.027	0.0743
Mn^{2+}	$mg \cdot dm^{-3}$	0.009	0.027
Zn^{2+}	$mg \cdot dm^{-3}$	0.0065	0.0198
SO_4^{2-}	$mg \cdot dm^{-3}$	0.01	1.00

RESULTS AND DISCUSSION

Changes in physicochemical indicators before and after the restoration of the Stara Nida branch

Changes in physical indicators

Figure 3 illustrates the physical indicators of water both before and after the restoration of the SN branch. These indicators include *T*, pH, *EC*, DO, and TDS. The Shapiro-Wilk test showed the normal distribution of all indicator values. Median values, obtained through the Wilcoxon (Mann-Whitney) rank sum test, highlight variations among various sampling points.

Water temperature is a crucial factor as it exerts substantial control over various physicochemical and biological reactions (Beyaitan Bantin et al., 2020). In this study, the Wilcoxon test revealed significant differences in temperature before and after the restoration of the SN branch flow at the sampling point SW1 (p-value = 0.042) – as illustrated in Figure 3a. No other significant differences were observed in this circumstance. It is important to note that water temperature is closely linked to ambient temperature and is significantly affected by seasonal changes (WHO 2017). Therefore, alterations in river morphology do not seem to influence water temperature

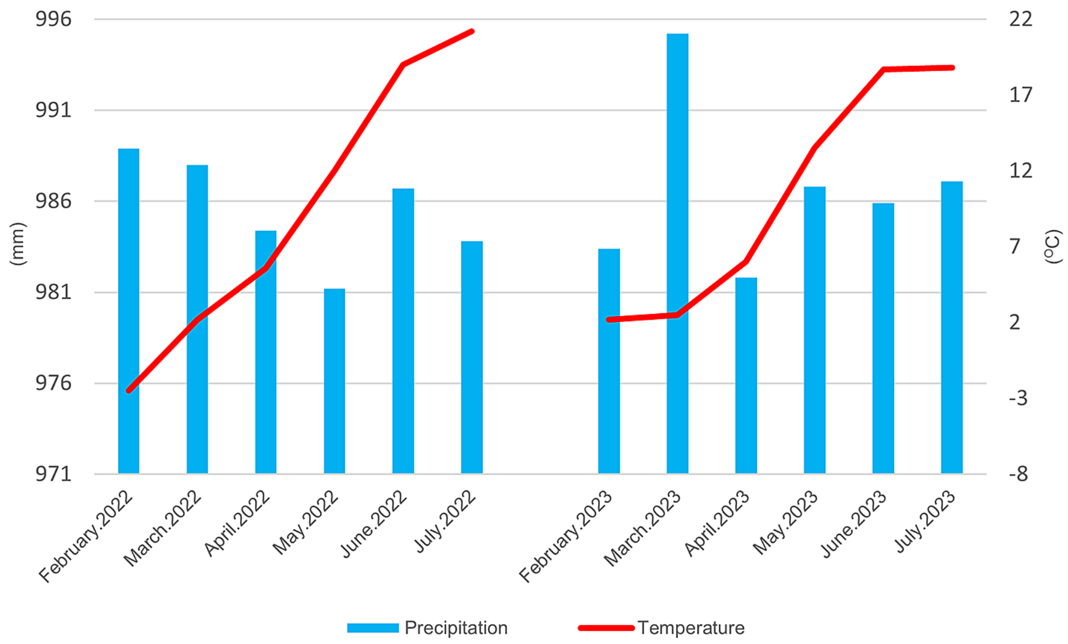

Fig. 2. Annual mean values of temperature and precipitation in the study area, source: own elaboration based on data of IMGW – PIB, Available at: https://hydro.imgw.pl

changes, which may be attributed to variations in weather temperature between observation years. The pH values are recognized as a pivotal indicator influencing whole of efficiency and biodiversity, with many biochemical activities intricately linked to pH value (Minns, 1989). The Wilcoxon test, depicted in Figure 3b, identified no significant differences in pH values before and after the restoration of the SN branch flow. Consequently, changes in river morphology do not appear to impact pH values in both GW and SW within the study area. Electrical conductivity (*EC*) values, regulated by hydrochemical processes such as salinity cycling and interactions between water and rock, offer insights into water mineralization, with variations corresponding to changes in dissolved salts concentration (El Maghraby et al., 2013). Additionally, temperature significantly affects *EC* by influencing salt dissolution (Benrabah et al., 2016). The Wilcoxon test revealed significant differences in *EC* values before and after the restoration of the SN branch flow at multiple sampling points (GW2, p-value = 0.007; GW5, p-value = 0.01; GW6, p-value = 0.018; GW7, p-value = 0.002; SW3, p-value = 0.003) – as shown in Figure 3c. These results indicate changes in *EC* values in both water collected at the SU branch and the GW in the riparian area when the SN branch flow occurs.

Dissolved oxygen (DO) serves as a critical indicator for water quality evaluation. In GW, DO levels are typically significantly lower compared to SW, primarily due to the infiltration of SW into underground streams carrying free oxygen (Subhan et al., 2008). The Wilcoxon test highlighted significant differences in DO values before and after the restoration of the SN branch flow at the sampling points GW1 (p-value = 0.004) and SW3 (p-value = 0.041), as depicted in Figure 3d. No significant differences were observed in other points. Total Dissolved Solids (*TDS*) of water include mineral salts originating from various sources, including natural processes, wastewater, rainwater, and industrial effluent. *TDS* concentrations vary significantly across geological zones due to distinctions in mineral dispersibility (WHO 2017). *TDS* is considered an indicator of saline water, reflects the appearance of natural solutes resulting from soil dissolving and rock erosion (Boyd, 1999). The observed variation in *TDS* mirrors that of EC.

Changes in chemical indicators

The chemical indicators (TP, TN, Cl^-, SO_4^{2-}, Mn^{2+}, $Fe^{2+,3+}$, Zn^{2+}, Pb^{2+}, Cd^{2+}, Cu^{2+}, COD) are presented at Figure 4. The Shapiro-Wilk test revealed the normal distribution of all indicators. Total phosphorus (TP) encompasses all kinds of phosphorus, including organophosphate and mineral phosphate (Dong et al., 2019). Phosphates in

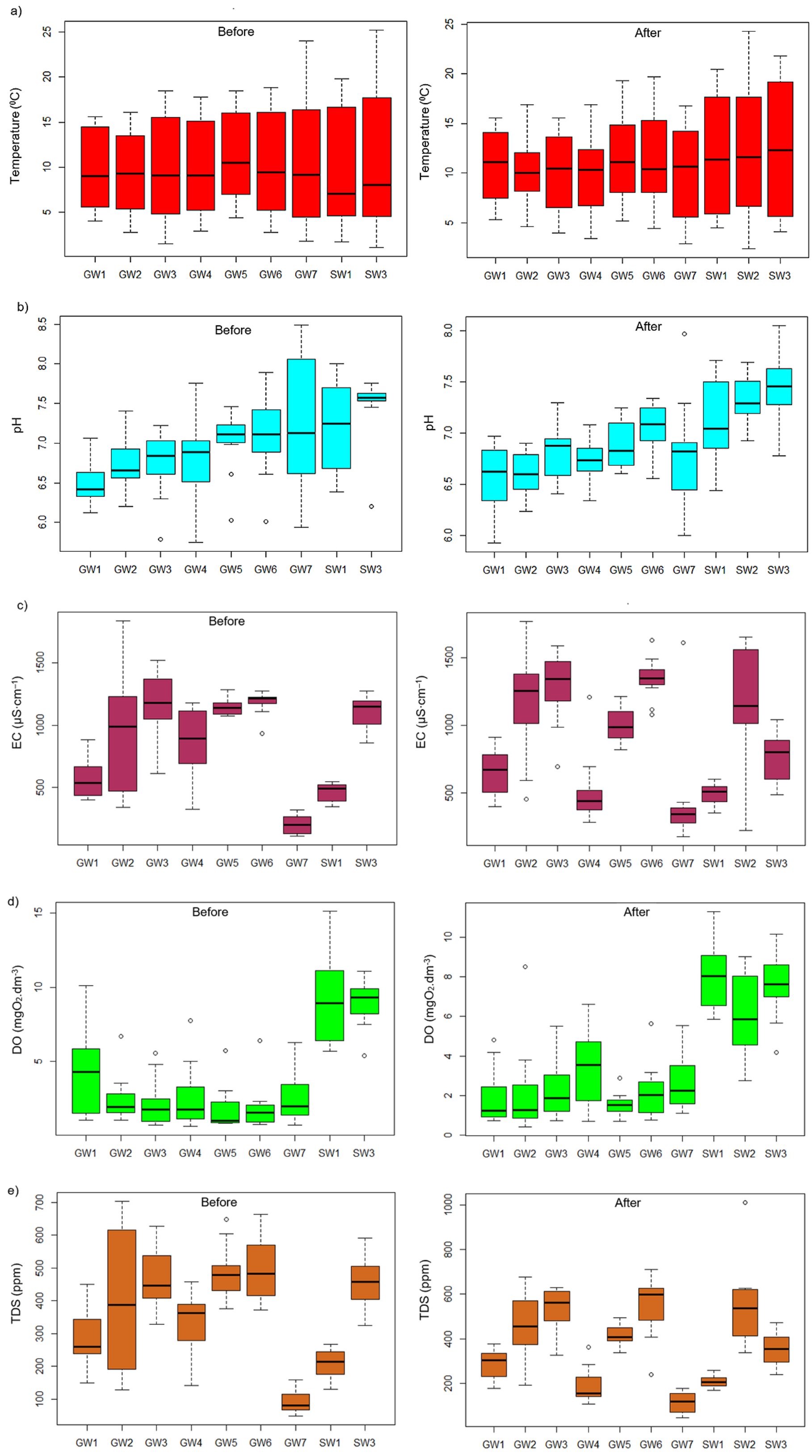

Fig. 3. Variations in the physical indicators of water before and after the restoration of the Stara Nida branch. The indicators examined include: (a) temperature (T), (b) pH, (c) electrical conductivity (EC), (d) dissolved oxygen (DO), (e) total dissolved solids (TDS). In the chart, each indicator is represented by a box-and-whisker plot. The average values for each point are displayed within the rectangles, along with the standard deviation limits. The minimum and maximum values are indicated by the whiskers, which extend to the lowest and highest values observed in that point. Any data points falling outside the whiskers and considered as outliers are represented by small circles

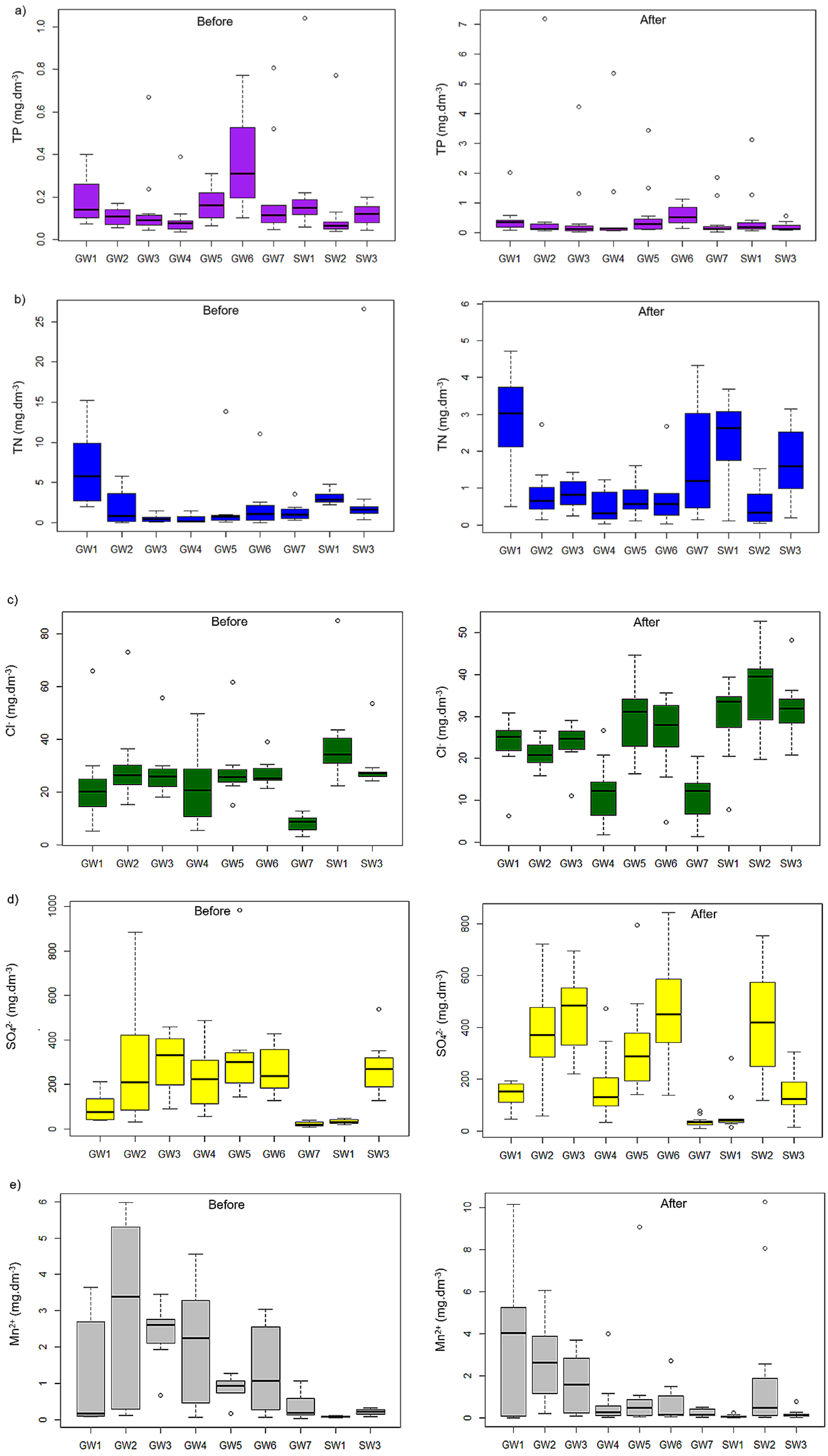

Fig. 4. Variations in the chemical indicators of water at observation points before and after the restoration of the Stara Nida branch: (a) total phosphorus (TP), (b) total nitrogen (TN), (c) chloride (Cl^-), (d) sulphate (SO_4^{2-}), (e) manganese (Mn^{2+})

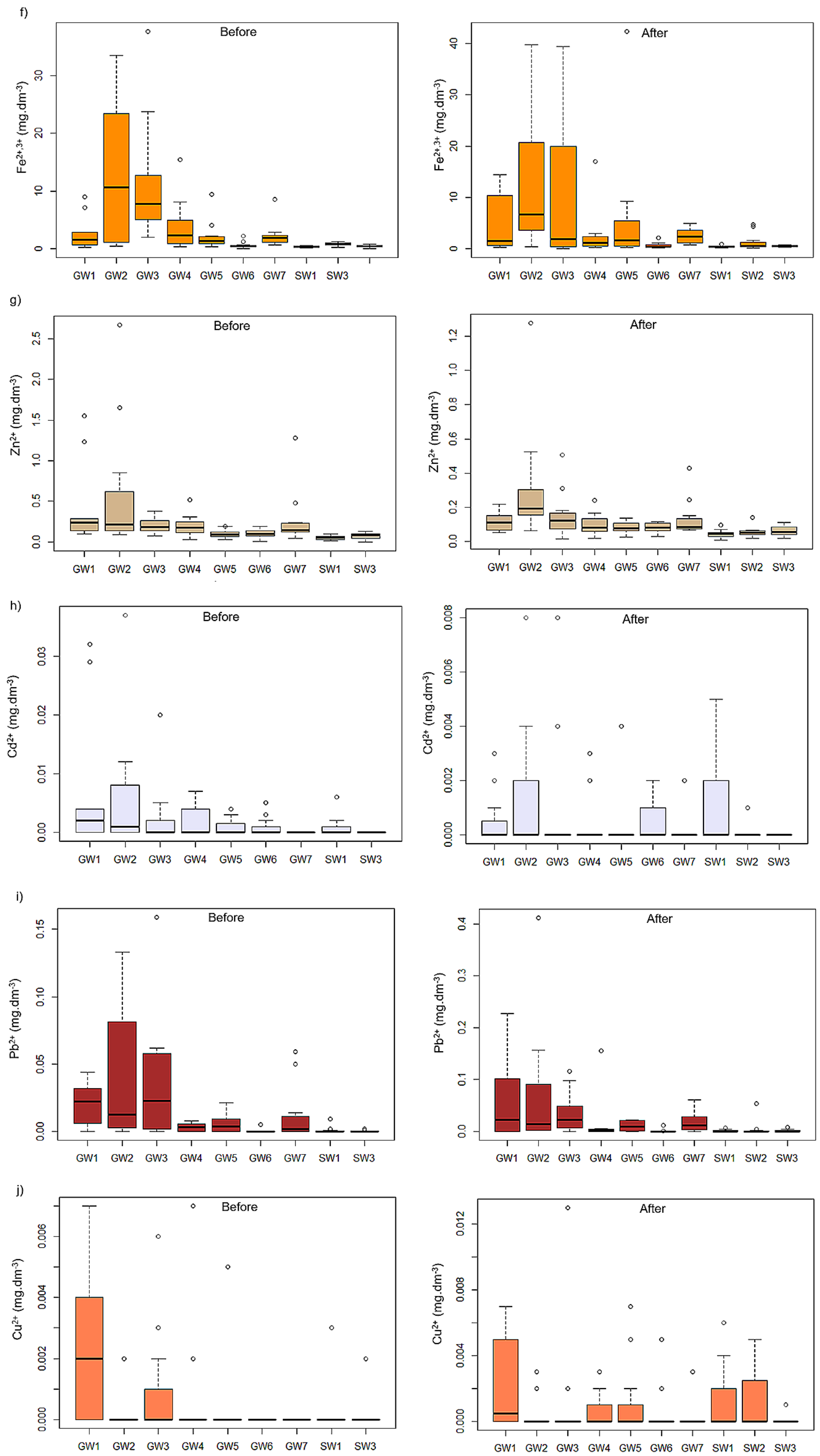

Fig. 4. Variations in the chemical indicators of water at observation points before and after the restoration of the Stara Nida branch: (f) iron ($Fe^{2+,3+}$), (g) zinc (Zn^{2+}), (h) cadmium (Cd^{2+}), (i) lead (Pb^{2+}), (j) copper (Cu^{2+})

water primarily stem from metals in parent rocks or pollution due to fertilizers, sewage, production waste, and human activities (Zanini et al., 1998; Krapac et al., 2002). The Wilcoxon test in this analysis revealed significant differences in TP values before and after the restoration of the SN branch flow at the sampling points of GW1 (p-value = 0.004), GW2 (p-value = 0.042), GW4 (p-value = 0.041), GW5 (p-value = 0.021), GW6 (p-value = 0.042) - as depicted in Figure 4a. No significant differences were observed at other points.

Total nitrogen (TN) comprises nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), and organically bonded nitrogen. The Wilcoxon test indicated no significant differences in TN values before and after the restoration of the SN branch flow at the sampling point, as shown in Figure 4b. This suggests that changes in the SN branch flow do not impact the nitrogen composition in the water at the research area. The concentration of chloride (Cl^-) remains stable in water and is naturally present in the compound of sodium and potassium. Its concentration is unaffected by living and nonliving processes (Popoola et al., 2019). The Wilcoxon test identified significant differences in Cl^- values before and after the restoration of the SN branch flow at the sampling point of GW2 (p-value = 0.007), with no significant differences at other points (Fig. 4c). Sulfates (SO_4^{2-}) occur naturally in various minerals, with high levels typically found in natural water like barium sulfate, magnesium sulfate heptahydrate and calcium sulfate dihydrate (Greenwood and Earnshaw, 1984). The Wilcoxon test revealed statistically significant differences in SO_4^{2-} values before and after the restoration of the SN branch flow at the sampling points of GW2 (p-value = 0.003) and SW3 (p-value = 0.012), while no significant differences were observed at other points (Fig. 4d).

Manganese (Mn^{2+}) is commonly found in association with iron and naturally occurs in many SW and GW sources, especially in environments with limited oxygen availability (WHO 2017). The Wilcoxon test indicated significant differences in Mn^{2+} values before and after the restoration of the SN branch flow at the sampling points of GW2 (p-value = 0.042), GW5 (p-value = 0.034), SW1 (p-value = 0.034), with no other statistically significant differences observed - Figure 4e. Iron ($Fe^{2+,3+}$) is abundant in crustal layer and is commonly discovered in water resources at concentrations limit from 0.5 to 50 $mg \cdot dm^{-3}$. The observed $Fe^{2+,3+}$ concentrations linked to the weathering of ferriferous minerals and rocks in the soil, as well as the dissolution of naturally occurring iron deposits into water through leaching (Popoola et al., 2019). The Wilcoxon test indicated no significant difference in $Fe^{2+,3+}$ values before and after the restoration of the SN branch flow at the sampling points (Fig. 4f). Zinc (Zn^{2+}) is naturally exist at small amounts in rocks and soils, mainly in the form of sulphide ores (ZnS) and carbonates ($ZnCO_3$) (Dohare et al., 2014). The Wilcoxon test revealed significant differences in Zn^{2+} values before and after the restoration of the SN branch flow at the sampling point of GW1 (p-value = 0.004), with no other statistically significant differences observed (Fig. 4g).

Cadmium (Cd^{2+}) is found in raw minerals and it is also a by-product of zinc purification (Wang et al., 2006). The Wilcoxon test revealed no significant differences in Cd^{2+} values before and after the restoration of the SN branch flow at the sampling points - Figure 4h. Lead (Pb^{2+}) primarily enters water via the dissolving lead-rich minerals, including lead glance, white lead ore and lead sulfate (WHO 2004). Rising lead concentrations in water samples are often linked to natural processes, resulting from the leaching of naturally occurring lead ore deposits in the soil (Imam, 2012). The Wilcoxon test revealed no significant differences in Pb^{2+} values before and after the restoration of the SN branch flow at the sampling points (Fig. 4i). Copper (Cu^{2+}) can be introduced into water through the dissolution of decomposition of copper-containing metals. Dissolving of copper is influenced by mineral carbon and pH. The Wilcoxon test revealed no significant differences in Cu^{2+} values before and after the restoration of the SN branch flow at the sampling points (Fig. 4j). The presence of copper was not detected in either GW or SW for many months, indicating minimal impact from production activities in the surveyed area.

Chemical oxygen demand (COD) quantifies the oxygen needed for the oxidative process of biomass. A higher COD value can be attributed to the dissolution of biomass and the inflow of underground flows carrying matter into the research area. The Wilcoxon test revealed no significant differences in *COD* values before and after the restoration of the SN branch flow at the sampling points of GW2 (p-value = 0.003), GW3 (p-value = 0.005), GW5 (p-value = 0.009), with no other statistically significant differences observed.

Changes in general physicochemical properties at sampling points due to the restoration of the Stara Nida branch

Pearson's correlation coefficient analysis method

Figure 5 performed the correlation matrix with the correlation coefficients (r) and their corresponding significance levels (p-values) indicating changes in physicochemical indicators for both SW and GW at sampling points before (SW, GW) and after (SW*, GW*) the restoration of the SN branch. Positive correlation was identified in all cases with p-values less than 0.001.

Notably, robust relationships were observed within the datasets comprising SW1 and SW1* (r = 0.83), SW3 and SW3* (r = 0.85), GW7 and GW7* (r = 0.91). Moreover, significant correlations were noted among the datasets of GW1 and GW1* (r = 0.79), GW3 and GW3* (r = 0.79), GW4 and GW4* (r = 0.76), GW6 and GW6* (r = 0.73). Additionally, weak correlations were detected between GW2 and GW2* (r = 0.49), GW5 and GW5* (r = 0.65) datasets. The findings emphasize discernible changes in the physicochemical composition and concentration of water before and after the restoration of the SN branch at sampling points. Particularly, no significant changes were found at sites SW1, SW3, and GW7 before and after the restoration. However, there were some changes at sites GW1, GW3, GW4, and GW6, with particularly substantial changes at GW2 and GW5. The results suggest that the restoration of the SN branch flow does not significantly affect the physicochemical indicators of water in existing SW flows in the study area (the NR and SU branch). Still, it has a considerable impact on GW in the riverside area, altering the physicochemical indicators of water to varying degrees at observation locations, especially those near branches of the SN and SU.

The lack of significant changes at sites SW1 and SW3 can be attributed to the interconnected nature of these streams, with both branches, SU and SN, originating from the main flow of the NR. These streams traverse the Nida valley, and their hydrochemical composition reflects the characteristics of this region, as discussed by Cel et al. in 2017. Additionally, Wojak et al. (2023), in their study found complex relationships between water flow and the riverbed, with variations in river discharge impacting both flow processes and water composition. The changes at sites GW1, GW3, GW4, GW6, and GW7, characterized by an elevated content of mineral ions, originate from rock

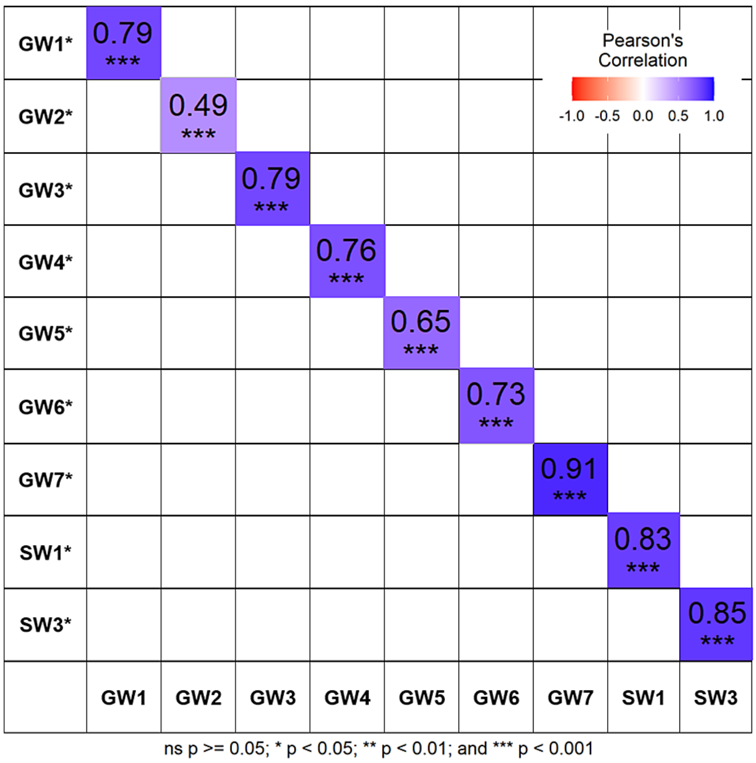

Fig. 5. Correlation matrix of physicochemical indicator changes before and after the restoration of the Stara Nida branch at observed points

erosion processes, as suggested by Nowobilska-Luberda (2018). Moreover, the physicochemical indicators of GW within the riparian area reveal the connection of GW between observation points throughout the research area. This phenomenon is explained by the unique topography of the Nida valley, a lowland area prone to prolonged flooding for many months, intensifying both water exchange and material transport processes, as discussed by Żelazo (1993), Łajczak (2004), and Strużyński et al. (2015). Additionally, significant content of Mn^{2+} and $Fe^{2+,3+}$ in GW has revealed in this area and notably high levels of these elements, emphasizing the existence of seasonal changes in GW properties (Phan et al., 2023b).

Furthermore, the substantial changes in physicochemical indicators of water at sites GW2 and GW5 are explained by the altered exchange processes between SW and GW when the SN branch flow is restored. This results in an increased amount of SW and GW in the area surrounding that branch of the river, subsequently reducing the water quantity in other branches of the river (Costello et al., 1984; Demaku and Bajraktari, 2019). To investigate the hypothesis regarding the influence of weather factors on substantial changes in the physical and chemical indicators of water at observation points, we analyzed temperature and precipitation monitoring data over the study period. The analysis employed the Pearson correlation coefficient. The results indicate robust positive correlations in temperature ($r = 0.98$, p-value < 0.001) and precipitation ($r = 0.8$, p-value < 0.01) between the periods before and after the restoration of the SN branch. This suggests that no significant differences were observed during the study period or that weather factors did not significantly impact the physicochemical indicators of the water. Figure 2 illustrates the detailed variations in weather factors.

CONCLUSIONS

This study employed environmental monitoring techniques to observe changes in physicochemical indicators at sampling points resulting from the restoration of the SN branch in the Nida valley, Poland. Statistical analyses, including the Shapiro-Wilk test ($\alpha = 0.05$) and Wilcoxon (Mann-Whitney) rank sum test ($\alpha = 0.05$), identified significant differences in various indicators pre- and post-restoration. Specifically, temperature at sampling point SW1, *EC* at multiple sampling points (GW2, GW5, GW6, GW7, and SW3), DO at GW1 and SW3, TP at GW1, GW2, GW4, GW5, GW6, Cl^- at GW2, SO_4^{2-} at GW2 and SW3, Mn^{2+} at GW2, GW5 and SW1, COD at GW2, GW3 and GW5, exhibited significant changes. No significant differences were observed for indicators at other points.

Pearson's correlation coefficient analysis ($\alpha = 0.001$) revealed discernible alterations in the physicochemical indicators of water before and after the restoration of the SN branch at various sampling points. Notably, no significant changes were observed at sites SW1, SW3, and GW7 before and after the restoration. However, observable changes were noted at sites GW1, GW3, GW4, and GW6, with particularly noteworthy changes at GW2 and GW5. The findings suggest that the restoration of the SN branch flow has a minimal impact on the physicochemical indicators of water in existing SW flows (the NR and SU branch) in the study area. However, it significantly influences GW in the riverside area, leading to varied alterations in the physical and chemical indicators of water at observation locations, particularly those near the branches of the SN and SU.

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