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First study of the influence of the coal fired power plants pollution in Bulgaria on the ecological status of the rivers

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Abstract

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This paper presents the first study devoted to the effect of coal fired power plants on the lotic ecosystems in Bulgaria. The study was carried out in 2023, in three Bulgarian rivers – Sokolitsa River, Razmetanitsa River and its tributary Kamenishka River. The effects of the pollution were assessed by changes in both macrozoobenthic communities (as biological quality element), and characteristics of aquatic environment. Macrozoobenthic samples were collected, and the basic physico-chemical parameters were measured before and after discharges of wastewaters from the facilities. Deterioration of the ecological status of the studied river after the places of the discharge of the polluted waters was established. The results showed that the coal fired power plants activities influenced negatively the affected river stretches by worsening the ecological situation of the adjacent aquatic ecosystems.

Keywords: coal fired power plants; macrozoobenthos; physico-chemical parameters; ecological status

Introduction

The phase-out of electricity generation from coal-fired power plants (CFPPs) in Europe, which is part of the fulfillment of the objectives for reducing greenhouse gas emissions under the Paris Agreement, must end until 2030 (PAUN, 2015). Several European countries, including Bulgaria, have not yet planned and specified deadlines for the closure of their CFPPs. Initially, in 2019, an indicative deadline of 2038 was proposed for Bulgaria. Subsequently, in 2024 the government proposes to close the Bulgarian CFPPs in 2040 (Bulgaria's URRP, 2023). In 2022, the contribution of the major CFPPs to the energy system of Bulgaria is still significant – they occupy 3848 MW (46%) from the total energy capacity of the country. (NSI, 2024; wp CFPP – Maritza East 2, 2024).

The majority of operating CFPPs in Bulgaria are technically outdated, do not use modern technologies and continue to be one of the main pollutants of the environment, including all its components – air, soil, water and biodiversity. The need to stop the operation of the CFPPs in Bulgaria is becoming increasingly visible in times of global climate change, prolonged economic and political crises, growing demand for energy security and consumption of energy resources. In the process of electicity producing through coal burning millions of cubic meters of water are polluted and huge amounts of solid wastes are obtained – ash, cinder, slag. They are deposited and stored outdoors, occupying and polluting vast areas. Relationship between the high values of the monitored and analyzed pollutants in the influenced rivers after the CFPP facilities and the worsening of the ecological status (biological quality elements, basic physico-chemical parameters, specific pollutants) and chemical status (priority substances) was established in the last preview of monitoring data for previous ten-year period 2013–2022, for Razmetanitsa River impacted by CFPP "Bobov dol" facilities and Sokolitsa River impacted by CFPP "Contur Global Maritsa East 3" facilities (detailed information can be seen in Mitseva & Varadinova, 2023). The CFPPs in Bulgaria still cause deterioration of the of the aquatic ecosystems and it was noted in the published Drafts of RBMPs 2022–2027, of WARBD and EARBD, Chapter 2 "Brief overview of significant types of pressures and impacts due to human activities on the status of surface and groundwater", where existing CFPPs have been assessed as significant types of pressure on the ecological and chemical status of the affected surface water bodies (Draft of RBMP of WARBD, 2024; Draft of RBMP of EARBD, 2024).

The aim of the study is to assess the impact of the wastewater discharges from existing CFPPs on the ecological status of the influenced rivers – Razmetanitsa River and its tributary Kamenishka River (West Aegean River Basin District) and Sokolitsa River (East Aegean River Basin District).

Materials and Methods

Study area

The study area covered surface water bodies located on Struma River catchment (West Aegean River Basin District) and Maritsa River catchment (East Aegean River Basin District), which are one of the most affected river catchments by CFPP-activities in Bulgaria (Fig. 1a and Fig.1b).

Detailed information about number and location of points of wastewater discharges from CFPP "Bobov dol" and CFPP "Contour Global Maritsa East 3" is presented in the previous study (Mitseva & Varadinova, 2023).

Data collection and analysis

The field measurements and samplings were carried out in the summer and autumn of 2023, in conditions of low water level of the studied rivers. In total seven surface water studied sites (located before and after points of discharge of wastewater from fuel facilities, sludge dumps, non-hazardous depot and waste landfills of CFPPs) in Razmetanitsa River catchment (including Kamenishka River) and Sokolitsa River catchment were included in this survey (Table 1).

The water samplings were carried out in accordance with standard EN ISO 5667-3:2018 "Water quality – Sampling – Part 3: Preservation and handling of water samples". The standard specifies general requirements for sampling, preservation, handling, transport and storage of all water samples including those for biological analyses.

The characteristics of the studied sites including codes of sites, geographic coordinates, belonging to surface water bodies, measured and analized quality elements and parameters in the water are presented in Table 1.

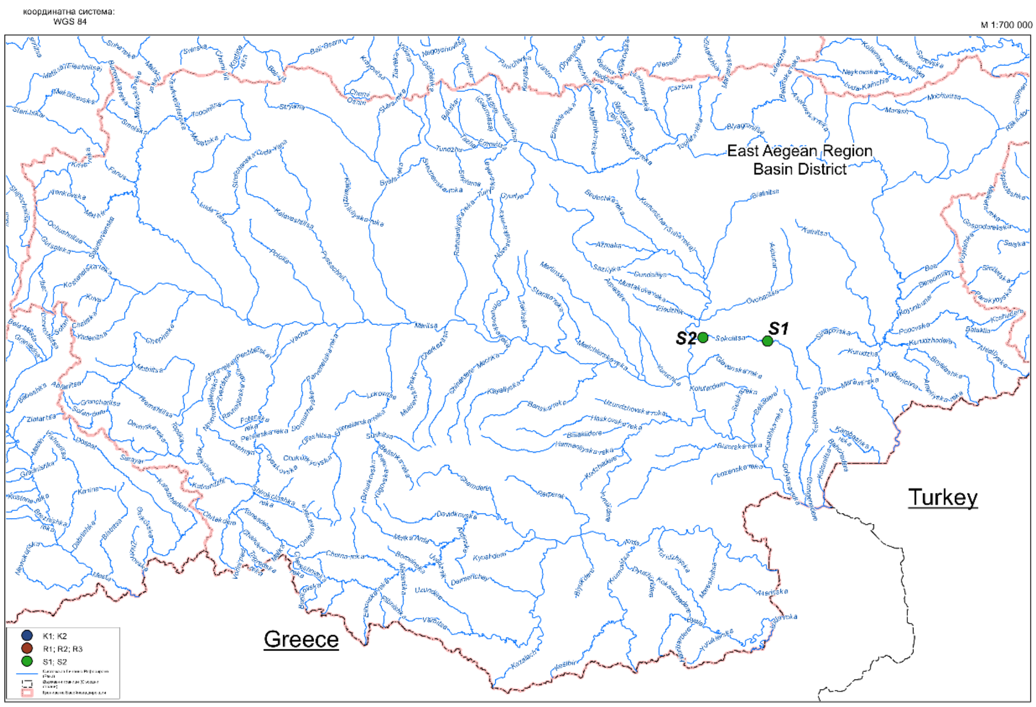

Fig. 1a. Location of the monitoring sites on Sokolitsa River in East Aegean Basin district in Bulgaria
Legend:
S1 – site Sokolitsa River near Vladimirovo village, before discharges of CFPP "Contour Global Maritsa East 3" and Landfill "Embankment Mednikarovo";
S2 – Sokolitsa River near Obruchishte village, after discharges of CFPP "Contour Global Maritsa East 3" facilities and Landfill "Embankment Mednikarovo"

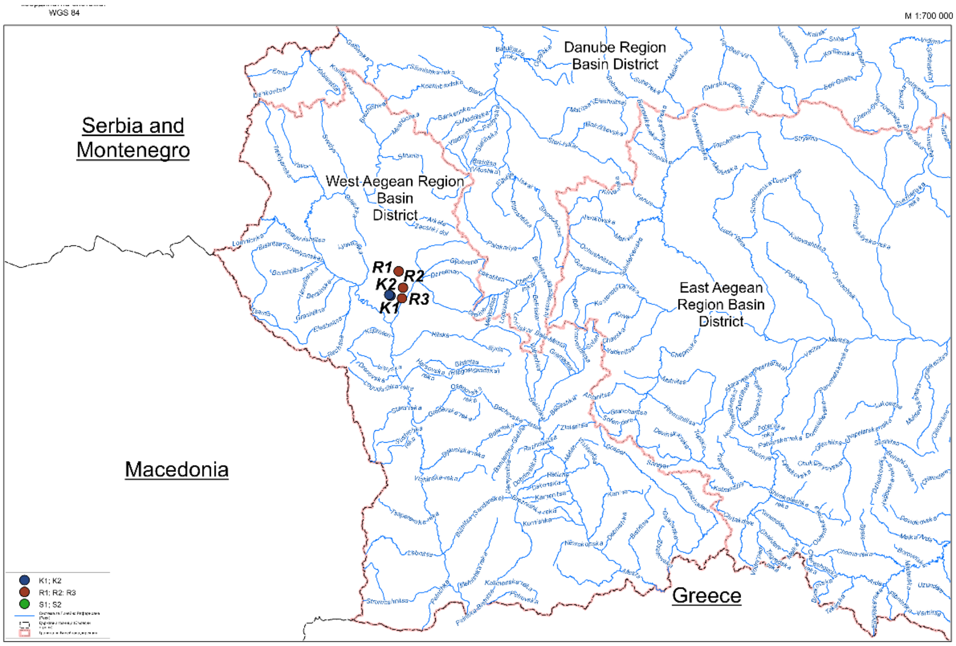

Fig. 1b. Location of the monitoring sites on Razmetanitsa River and Kamenishka River in West Aegean Basin district in Bulgaria

Legend:

R1 – site Razmetanitsa River before discharges of "Black lake" sludge dump of CFPP "Bobov dol", Golemo selo village;

R2 – site Razmetanitsa River immediately after discharges of "Black lake" sludge dump of CFPP "Bobov dol", Balanovo village;

R3 – site Razmetanitsa River after all discharges of CFPP "Bobov dol" (after confluence of Kamenishka River) and before inflow in Dzherman River;

K1 – site Kamenishka River before "Kamenik" landfill of CFPP "Bobov dol";

K2 – site Kamenishka River after "Kamenik" landfill of CFPP "Bobov dol"

Macrozoobenthos (MZB) was taken through multi-habitat sampling approach, using a hand net (mesh size 500 µm) and a set of hydrobiological sieves for sandy and silt substrata (Cheshmedjiev et al. 2011), according to the standards BDS EN ISO 10870:2012 and EN 16150:2012. The laboratory processing included separation and determination of the macroinvertebrates by main taxonomic groups.

The obtained results for the values of the basic physico-chemical parameters (pH, dissolved oxygen (DO), conductivity (Cond), ammonium nitrogen (N-NH4), nitrite nitrogen (N-NO2), nitrate nitrogen (N-NO3), total nitrogen (N-total), orthophosphates such as phosphorus (P-PO4), total phosphorus (P-total) in matrix "water") were compared with their relevant values of „Good ecological status" for river type R13 – Small and medium plain Aegean rivers (Ordinance N-4/2012). Physico-chemical assessment was defined by the most unfavorable among all studied parameters. Biological evaluation of the studied river sections was assessed using the Biotic index(BI) which is based on MZB according to a river-type specific scale developed in the national legislation (Regulation № Н-4, 2012). Final ES estimation was determined by the worse of the biological and physico-chemical assessment.

Statistical analyses

Ordination PCA analysis with supplementary variables method (CANOCO 5 package) was applied to visualize the species-site-factor relations and distributions. Cluster analyses (Bray-Curtis similarity, complete linkage, Primer v6) was used to present the similarity between macroinvertebrates taxonomic groups of the studied sites. Data for a previous ten-year time period (see Mitseva & Varadinova, 2023) were used to trace and show the change of the observed parameters and quality elements of the ecological status of the studied rivers over time.

Results

Physico-chemical parameters.

Measured basic physico-chemical parameters pH, DO and Cond of the water environment in the studied sites showed the widest range of the Cond values with highest registered on site R3 and relatively closer values of the pH and DO (Fig. 2).

Nutrients are characterized by increasing of the values at the sites after the discharges compared to the reference sites located above the impact places of the studied rivers (Fig. 3 and Fig. 4). Raising of the concentrations of the nitrogen-containing nutrients N-NH_4, N-NO_2, N-NO_3 and N-total in all sites after CFPPs wastewater discharging points (R2, R3, K2 and S2) was measured. The highest values of nitrogen-containing nutrients N-NH_4, N-NO_2, N-NO_3 and N-total are measured in sites S1 and S2 on Sokolitsa River. Increasing of the values of the P-PO_4 and P-total in all sites located after

Table 1. Characteristics of the studied sites

№	Name of studied site	Coordinates of monitoring site	Surface water body code, name and type	Main river catchment	Quality elements, parameters and substances measured in situ and/or sampled for analysis in matrix "Water"
1	R1, Razmetanitsa River before discharges of "Black lake" sludge dump of CFPP "Bobov dol", Golemo selo village	23°2′24,021″E, 42°17′23,632″N	BG4ST600R039, Razmetanitsa River from the springs to the confluence with Dzherman River, type R13	Struma	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.
2	R2, Razmetanitsa River immediately after discharges of "Black lake" sludge dump of CFPP "Bobov dol", Balanovo village	23°3′32.76″E, 42°14′43.8″N	BG4ST600R039, Razmetanitsa River from the springs to the confluence with Dzherman River, type R13	Struma	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.
3	R3, Razmetanitsa River after all discharges of CFPP "Bobov dol" (after confluence of Kamenishka River) and before inflow in Dzherman River	23°3′25,92″E, 42°13′0,84″N	BG4ST600R039, Razmetanitsa River from the springs to the confluence with Dzherman River, type R13	Struma	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.
4	K1, Kamenishka River before "Kamenik" landfill of CFPP "Bobov dol"	23°0′34,654″E, 42°13′30,024″N	BG4ST600R039, Razmetanitsa River from the springs to the confluence with Dzherman River, type R13	Struma	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.
5	K2, Kamenishka River after "Kamenik" landfill of CFPP "Bobov dol" (before confluence in Razmetanitsa River)	23°0′52,934″E, 42°13′20,112″N	BG4ST600R039, Razmetanitsa River from the springs to the confluence with Dzherman River, type R13	Struma	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.
6	S1, Sokolitsa River near Vladimirovo village, before discharges of CFPP „Contour Global Maritsa East 3" facilities and Landfill "Embankment Mednikarovo"	26°8′11.76″E, 42°7′38.64″N	BG3MA200R018, Sokolitsa River upper stream	Maritsa	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), sulphates (mg/l), BQE Macrozoobenthos.
7	S2, Sokolitsa River near Obruchishte village, after discharges of CFPP „Contour Global Maritsa East 3" facilities and Landfill "Embankment Mednikarovo"	25°55′8.4″E, 42°8′5.64″N	BG3MA200R017, Sokolitsa River middle reaches to Rozov kladenets Dam	Maritsa	t° C, pH, dissolved oxygen (mg/l), conductivity (µS/cm), ammonium nitrogen (mg/l), nitrite nitrogen (mg/l), nitrate nitrogen (mg/l), orthophosphates such as phosphorus (mg/l), total phosphorus (mg/l), BQE Macrozoobenthos.

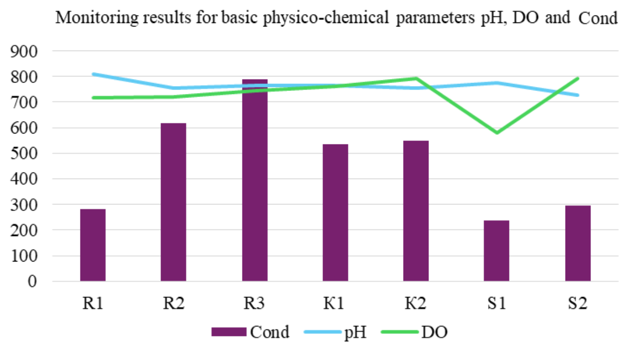

Fig. 2. Values of physico-chemical parameters pH, DO and Cond in the studied sites before and after CFPPs wastewater discharge points for Razmetanitsa River (studied sites R1, R2, R3), Kamenishka River (studied sites K1and K2) and Sokolitsa River (studied sites S1 and S2)

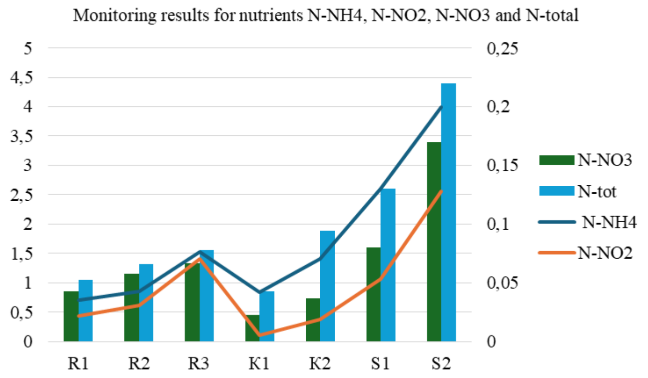

Fig. 3. Values of nitrogen-containing nutrients at the sites before and after CFPPs wastewater discharge points for Razmetanitsa River, Kamenishka River and Sokolitsa River in 2023

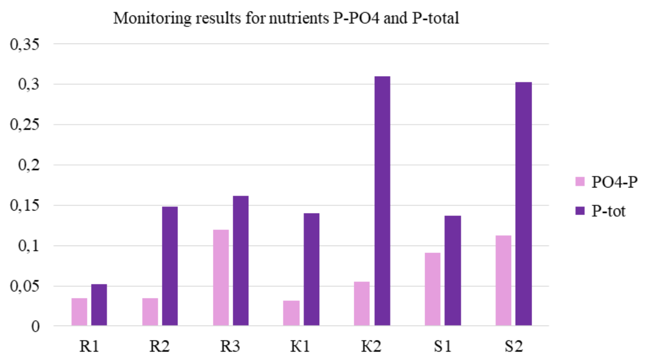

Fig. 4. Values of phosphorous-containing nutrients at the sites located before and after CFPPs wastewater discharge points for Razmetanitsa River, Kamenishka River and Sokolitsa River

CFPPs wastewater discharging points (R2, R3, K2 and S2) was registered: The highest value of P-PO_4 was measured at site K2 while the highest value of P-total was registered at site S2.

Macrozoobentic community

A percentage share of the macrozoobenthic composition presented by the main taxonomic groups was made separately for each of the studied rivers – Razmetanitsa River (Fig. 5a, 5b and 5c), Kamenishka River (Fig. 6) and

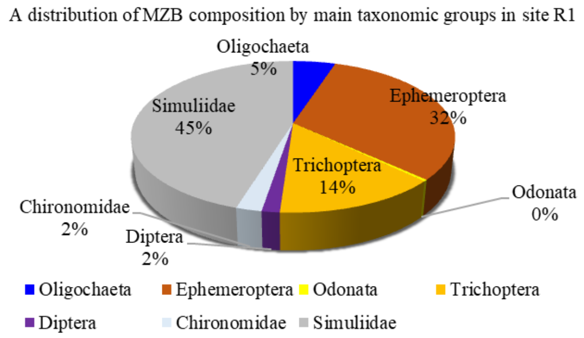

Fig. 5a. Percentage share of the main taxonomic groups at site R1, Razmetanitsa River

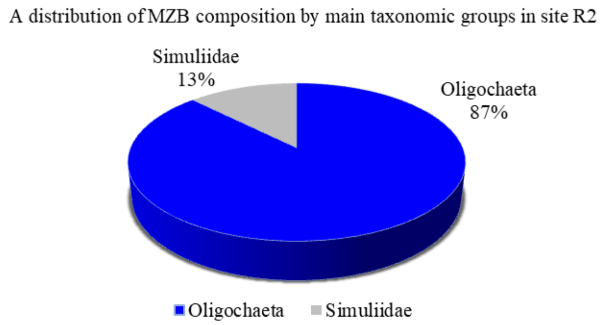

Fig. 5b. Percentage share of the main taxonomic groups at site R2, Razmetanitsa River

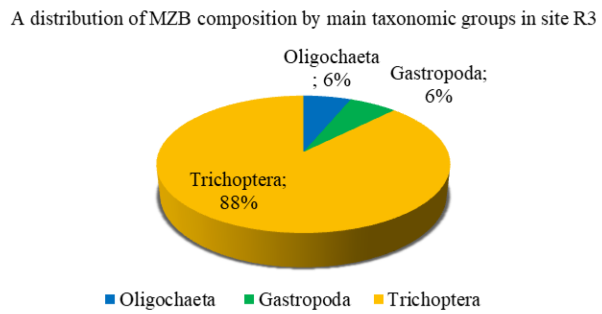

Fig. 5c. Percentage share of the main taxonomic groups at site R3, Razmetanitsa River

Sokolitsa River (Fig.7a and 7b). A significant reduction in the taxonomic composition of the MZB was observed at site R2 compared to R1. The invertebrate community found at site R2 was composed only of representatives of aquatic oligochaete worms and one black fly larva (Fig. 5a and 5b). Although an increase in taxonomic richness, which was registered at site R3 (which is farthest from the points of discharge of wastewater of CFPP „Bobov dol“), the MZB maintained a poorer composition than what was found at site R1. At site R3 the community was dominated by the tolerant taxa of the genus *Hydropsyche* (Fig. 5c). A comparison between the distribution of the macrozoobenthic composition, which were registered at site K1 and site K2, cannot be made because of dried up Kamenishka River at the stretch, where site K1 was situated during the field survey. The aquatic invertebrates found at site K2 were characterized by a predominant presence of more pollution-resistant, dipteran larvae (Fig. 6).

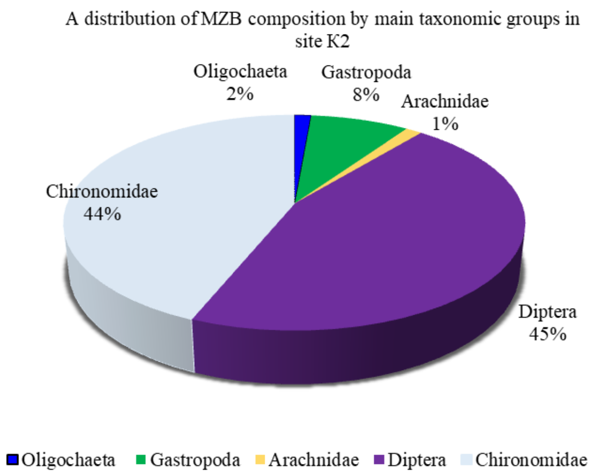

Fig. 6. Percentage share of the main taxonomic groups at site K2, Kamenishka River

Site S1 was characterized by a rich and diverse benthic community. Its composition was dominated by mayfly (Fig.7a). A significant reduction in the share of the order Ephemeroptera at the expense of anincrease of the dragonfly larvae at the S2 was found. (Fig 7b).

The cluster analysis of the taxonomic composition of the macrozoobenthos (Fig. 8) clearly separates in one group the unaffected sites located before the wastewaters discharge points of CFPP “Bobov dol” and CFPP “Contur Global Maritsa East 3”.

PCA analyses showed that the first two principal components cumulatively explained 71.26% of the total variance of the data. The first axes correlated most significantly and negatively with pH (-0.807) and conductivity. The second axes correlated positively with water temperature (0.905) and nutrients N-tot (0.780). The ordination diagram, which demonstrated the benthic groups and the studied sites distribution’ (Fig. 9a), separated the refer-

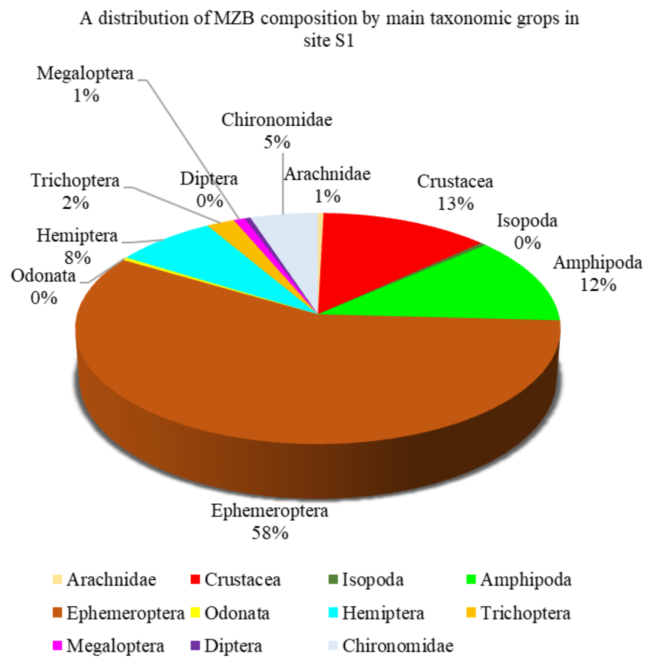

Fig. 7a. Percentage share of the main taxonomic groups at site S1, Sokolitsa River

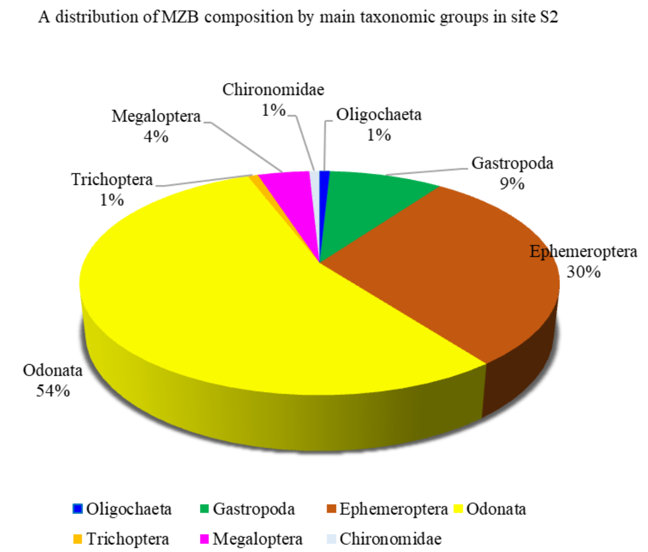

Fig. 7b. Percentage share of the main taxonomic groups at site S2, Sokolitsa River

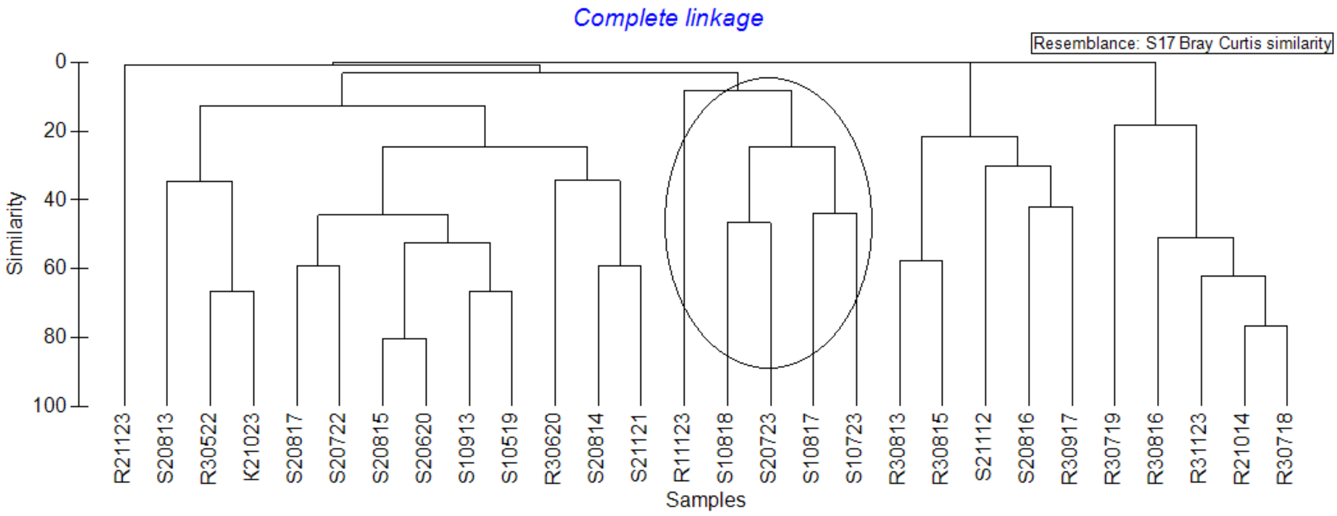

Fig. 8. Cluster analysis of the taxonomic composition of the MZB at the studied sites for the period 2013–2023

ence (left side of the diagram) from the influenced sites (right side of the diagram). Thus, the „unaffected right half of the ordination space was presented with greater taxonomic richness and an aquatic environment which was characterized by lower values of Cond and nutrients (Fig. 9b).

Ecological status evaluation

The results of the assessment based on biological quality element MZB and physico-chemical parameters, showed worsening of the ecological status (ES) at the sites situated after sources of negative influences (R2, R3 and K2, S2), in comparison with the referent sites (R1, S1) (Table 2).

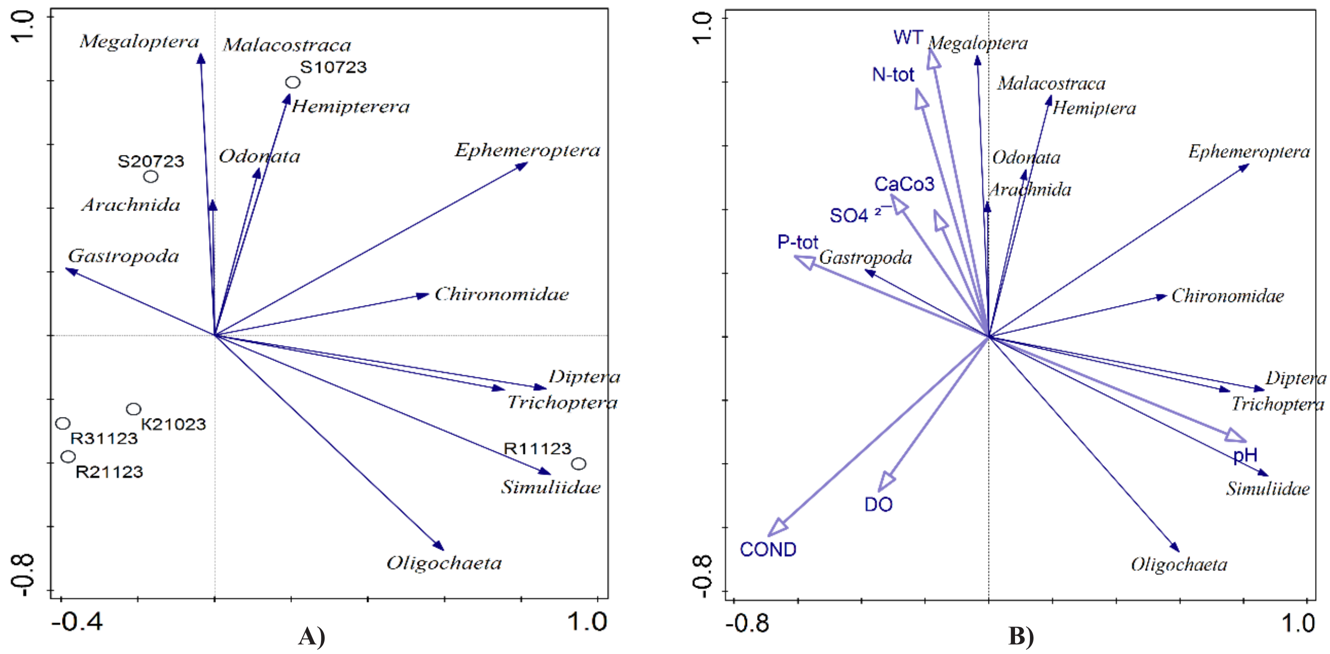

Fig. 9. PCA ordination diagram of groups-sites (9a) and groups-factors (9b) distribution of the MZB groups in 2023 (eigenvalues λ1 = 0.484; λ2 = 0.228)

Table 2. Ecological status of studied rivers in monitoring sites

Studied sites	River	Assessment of the ES by BQE MZB	Assessment of the ES by physico-chemical parameters	Final assessment of the ES by all studied quality elements and parameters	Quality elements and parameters, causeing deterioration of ES
R1	Razmetanitsa River	Moderate ES	Moderate ES	Moderate ES	Dissolved oxigen, Macrozoobentos
R2	Razmetanitsa River	Bad ES	Good ES	Bad ES	Macrozoobentos
R3	Razmetanitsa River	Bad ES	Moderate ES	Bad ES	Nitrite nitrogen
K1	Kamenishka River	No data	Good ES	Good ES	No worsened indicators and parameters were found
K2	Kamenishka River	Bad ES	Moderate ES	Bad ES	Total phosphorous, Macrozoobentos
S1	Sokolitsa River	Good ES	Moderate ES	Moderate ES	Total nitrogen,
S2	Sokolitsa River	Moderate ES	Moderate ES	Moderate ES	Nitrite nitrogen, Nitrate nitrogen, Total nitrogen, Total phosphorous, Macrozoobentos

Assessment of the ES of Razmetanitsa River defined by BQE MZB worsening by 2 classes – from Moderate ES at site R1 (before CFPPs facilities) to Bad ES at sites R2 and R3 (after CFPPs facilities). Kamenishka River was also determined in a Bad ES at site K2 (after CFPPs facilities). Sokolitsa River degraded its ES from Good at site S1 to Moderate at site S2.

ES evaluated through basic physico-chemical parameters measured at studied sites at Kamenishka River showed worsening by 1 class – from Good ES at site K1 (before CFPPs facilities) to Moderate ES at site K2 (after CFPPs facilities). Kamenishka River was also estimated in Bad ES by BQE MZB at site K2 (after CFPPs facilities). Sokolitsa River does not change the Moderate ES determined by basic physico-chemical parameters at sites S1 and S2 (before and after CFPPs facilities), but the number of the worsened parameters, has increased at site S2 (four parameters – TN, $N\text{-}NO_2$, $N\text{-}NO_3$, TP) compare to site S1 (only TN) (Fig. 3 and Fig. 4).

Discussion

The activity of CFPPs and the discharge of wastewater from them have an adverse effect on the affected river stretches (NRDC, 2014: Sybekmitova, 2021; Ngamlana et al., 2024). Our study confirmed the negative impacts of CFPPs on studied Bulgarian rivers. A deterioration of the aquatic environment characteristics' was observed. An increase in Cond (Fig. 2) and nutrients ($N\text{-}NO_2$, $N\text{-}NO_3$, N-tot, PO_4-P, P-tot), at all sites situated after the CFPPs facilities wastewater discharges was observed (Fig. 3 and Fig. 4) after CFPPs. It should be noted that the parameters pH and DO did not show significant changes in the values measured at the studied sites (Fig. 2). One exception with the lowest value of DO was registered at the referent site S1. The probable reason for the relatively unchanged oxygen values found before and after the impacts could be another type of pressure. Previous studies carried out in the basins of the Razmetanitsa River and Sokolitsa River showed negative impact from point discharges of non-treated wastewaters from settlements was determined (RBMP of WARBD, 2024; RBMP of EARBD, 2024). This unfavorable influence was more pronounced in the Sokolitsa River, respectively, at the site S1. Deteriorated oxygen parameters led to „moderate" ES at the sites R1 and S1 in terms of physico-chemical quality elements (Table 2). Because of the cumulative effect of the two types of anthropogenic pressure, for the purposses of the next investigation it will be very important to distinguish the origin and the degree of impact of each one of them.

Environmental conditions have a major influence on the type and continuity of MZB (Chazanah et al, 2020). The changes in the physico-chemical characteristics that occurred after the impact sites were significant. Thus, the sites before CFPPs were separated from the affected ones and were clearly distinguishable, which is evident in the presented statistical analyses (Fig. 8 and Fig. 9). Unfavorable changes in the aquatic environment, result of anthropogenic impact may lead to a decrease in diversity of the aquatic animals (Brysiewicz et al., 2022). Conductivity and nutrients can be regarded as major variables that play a crucial role in explaining the distribution of benthic macroinvertebrates in rivers (Lewin et al., 2013; Yu et al., 2024). The altered habitat conditions of the post-impact sites caused negative effect of the more sensitive benthic groups and reduction of the taxonomic diversity (Fig. 5, Fig. 6 and Fig. 7). The increase of nutrient is associated with a decreasing of the order Ephemeroptera and dominant presence of subclass Oligochaeta and family Chironomidae at sites K2 and R2 (Fig. 5, Fig. 6 and Fig. 7).

Changes in MZB structure under the effect of anthropogenic factors are mostly due to the stimulating effect of organic matter input and the suppressing effect of heavy metals and organic matter decay products (nitrogen compounds) (Bezmaternykh, 2018). Unlike the hydrochemical parameters, which characterize the water quality at the moment of sampling, the response of MZB is delayed, reflecting a prolonged effect of factors of different types (Semenchenko et al., 2024). Unfavorable aquatic environment was reflected in the worsened ecological assessment determined by the MZB, which was registered after places of the impacts (Table 2). This is evident even at the Razmetanitsa river, where despite the fact that the reference site R1 is affected by other negative impacts (Mitseva & Varadinova, 2023 and RBMPs 2022–2027 of WARBD, 2024), after the point of the CFPPs wastewater discharges, ES had changed from Moderate to Bad.

The evaluation of the ecological status based on the physico-chemical and BQE MZB unequivocally revealed deterioration of the ES at the sites located after the CFPPs wastewater discharges in the three studied rivers compared to the ES estimated at the sites before places of impact, which is indicative for the negative effect of the CFPPs on the studied lotic ecosystems.

Conclusions

This study for the first time analyzed the impact of the CFPPs on the running surface waters in Bulgaria. CFPPs activities change in a negative aspect the characteristics of the aquatic habitats and reduce the taxonomic richness of the macrozoobenthic communities. These caused adverse effect on the ecological situation in the lotic ecosystems.

It is necessary to carry out additional studies and include additional indicators e.g. other biological quality elements, both specific pollutants and priority substances in matrices water, biota and sediments to make comprehensive assessment of the effect of the CFPPs impact.

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