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Correlation between physical and chemical parameters of water and biotic indices: The case study the White Drin River basin, Kosovo

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Abstract

The major impacts on aquatic ecosystems worldwide caused by land use lead to changes in their natural conditions and limitation of water use for various needs. This paper presents the results of the study of the physical and chemical parameters and macroinvertebrate assemblage in the White Drin River (or: the Drim River, Alb. the Drini i Bardhë River) basin, the largest in Kosovo. Macroinvertebrate sampled at 11 sites in the river resulted in 5946 collected benthic organisms, which in taxonomic terms belong to 12 orders and 51 families. Of the total number of organisms, 72.28% were Insects, 25.39% Amphipoda crustaceans and 2.33% were Annelide worms and Mollusk. The used biotic indices Biological Monitoring Working Party (BMWP), Ephemeroptera, Plecoptera, and Trichoptera (EPT), average score per taxon (ASPT) and Stroud Water Research Center (SWRC) classify water quality in excellent category in the sampling site S1 near the source of the White Drin River, whereas in other sampling sites, as a result of pollution, water quality varies on category II–IV. The Pearson's correlation analyses shown that the physical and chemical parameters affect the water quality and the composition of macroinvertebrates. Our results show that the parameters that adversely affect the BMWP, EPT and ASPT biotic indices as well as the Shannon–Wiener, Mergalef and Menhinik diversity indices are: pH, electrical conductivity (*EC*), total suspended solids (*TSS*), nitrates (NO_3^-) and chlorides (Cl^-). We can conclude that the anthropogenic impact on White Drin basin affects the physical, chemical and biological parameters of the water therefore these parameters should be constantly included in Biomonitoring and Management plans for water resources in Kosovo.

Key words: *biotic index, diversity index, macroinvertebrate assemblage, pollution, the White Drin River basin*

INTRODUCTION

Water is a crucial natural resource, a basic human need and a precious natural asset. Recent years, water pollution has become a very serious problem, due to change of chemical, physical and biological components of waters. The availability and quality of water either surface or ground, have been deteriorated due to some important factors such as increasing population, industrialization, urbanization, etc. Moreover, inadequate management of water systems can cause serious problems in the water quality. Although a small country, Kosovo is facing with water pollution problems. As the main sources of water pollution in Kosovo in the recent years are untreated wastewaters, pesticides and fertilizers and industrial waters which discharge directly in rivers. One of the major world problems is a drastic reduction of water resources. Many people worldwide suffer from the lack of safe and quality water, which is essential for population needs. In many countries, water resources are depleted faster than they can be renewed and not enough for the demands of modern human life. This problem is getting worse day by day due to demographic growth sputtering, which is directly related to the contamination of water sources. For very long period river waters are used for drinking, domestic use, irrigation, in industrial processes, for recreation and fishing. Today, pollution of water with different contaminants presents a serious problem and often limits their use, therefor continuous monitoring of water is important to evaluate their quality. Water quality can be the best described with physical and chemical and biological parameters. Among the aquatic organisms, macroinvertebrates have a long history of application in water quality assessment. The study of river benthic macroinvertebrates for biological monitoring techniques has been widely reported and described in the literature [MANDAVILLE 2002; ROSENBERG, RESH 1993], resulting in a large variety of indices [DE PAUW *et al.* 2006; ROSENBERG, RESH 1993]. Results by ILIOPOULOU-GEORGUDAKI *et al.* [2003] showed that the use of macroinvertebrates as bioindicators for the assessment of water quality has more advantages than those based on diatoms, fish, riparian and aquatic vegetation. Biomonitoring is considered as the most appropriate method for environmental studies and for the control of water quality, due to that living organisms are excellent biosensors of the physicochemical and biological characteristics of water [KHOLODKEVICH *et al.* 2008].

The most commonly used variables to monitor water quality at present include physical and chemical attributes (e.g., water temperature, water reaction pH, electrical conductivity, total dissolved solids, dissolved oxygen, oxygen saturation, chemical oxygen demand, biochemical oxygen demand, total organic carbon, phosphate, nitrate, nitrite, and ammonium ion) as well as biological attributes (e.g., benthic macroinvertebrates, fish, algae and bacteria). Only measurement of physical and chemical parameters does not present an overview of realistic and complete picture of the ecological status of the flowing waters, as they only reflect water quality at the moment of sampling [ALBA-TERCEDOR 1996; METCALFE 1989]. On the other side, biological communities provide a more faithful reflection of environmental conditions, since they are continually exposed to them [ROSENBERG, RESH 1993].

Macroinvertebrates as indicators reflect not only current conditions, but also extreme conditions that have reigned in the past [HILSENHOFF 1977]. The composition of the macroinvertebrate community and their abundance in rivers are key components for the more comprehensive characterization and assessment of the ecological status of rivers, as foreseen in Water Framework Directive (WFD).

Generally, the use of indices requires prior modification according to environmental conditions or pollution types. The BMWP (Biological Monitoring Working Party) score system which has been developed for river pollution surveys in the UK [ARMITAGE *et al*. 1983], have been successfully applied in other countries, including Greece [ARTEMIADOU, LAZARIDOU 2005], Poland [CZERNIAWSKA-KUSZA 2005], Portugal [FARIA *et al.* 2006], Malaysia [AZRINA *et al*. 2006], Turkey [ZEYBEK *et al*. 2014], etc.

The monitoring of water quality is an important component of water management, essential for the water quality assessment. Therefore, the effective monitoring and the assessment of surface water quality are crucial in protecting the aquatic life. White Drin River basin is the biggest among four river basins in Kosovo. It runs in the western part of the country and discharges in Adriatic Sea in Albania. The basin has many sub-basins, but 9 of them are large and play important role for the population of this area. In terms of ecoregions, it belongs to Ecoregion 6 (Hellenic Western Ballkans). The spring/source of White Drin River forms a beautiful waterwall in Radavci village at an altitude from 586 m a.s.l, which is an attraction for many visitors. The length of the White Drin River basin is 122 km, whereas the catchment area is 4,646 km^2. The water from White Drin is used for drinking, irrigation, gravel excavation, tourism, fishing, livestock production and other purposes. The main way of land use alongside the White Drin River is agriculture. Throughout its course, the White Drin receives many discharges of different origin, such as untreated wastewaters from the settlements (including big cities), agricultural runoff rich in pesticides and fertilizers, discharges from animal farms, industrial discharges and other anthropogenic pollution sources.

The aim of this work was to evaluate water quality in the White Drin River using physical and chemical parameters and macroinvertebrate organisms. We tried to answer following questions.

1. How macroinvertebrate communities respond to changes in physical and chemical parameters of the environment, caused by different anthropogenic disturbances?
2. Do the biotic indices reflect the water quality?
3. If are there correlations between biotic indices and physical and chemical parameters; are the correlations positive or negative, and, which of these environmental parameters adversely impact the macroinvertebrate assemblage?

MATERIALS AND METHODS

STUDY AREA

With the aim to assess the water quality of the White Drin river basin, we took water samples to measure physical and chemical parameters and macroinvertebrate composition in 11 sampling sites alongside river basin in three seasons (spring, summer and autumn) in 2017.

The first sampling station was upstream, about 1 km from the spring, in village Radavc. We considered this sampling site as natural and undisturbed site which meets the criteria to be reference site. The other 10 samples were taken in three sub-basins (tributaries) of White Drin basin: the Klina River – 439 km^2 (S2, S3 and S4); the Mirusha River –335km^2 (S5, S6 and S7) and the Toplluha River – 500 km^2 (S8, S9, S10 and S11) – Figure 1.

Four, among the 11 sampling sites, belong to the mainstream of the White Drin River: S1, S4, S7 and S11. The water and macroinvertebrate samples in three sub-basins were taken upstream, mid-stream and downstream. The characteristics of sampling sites are presented in Table 1.

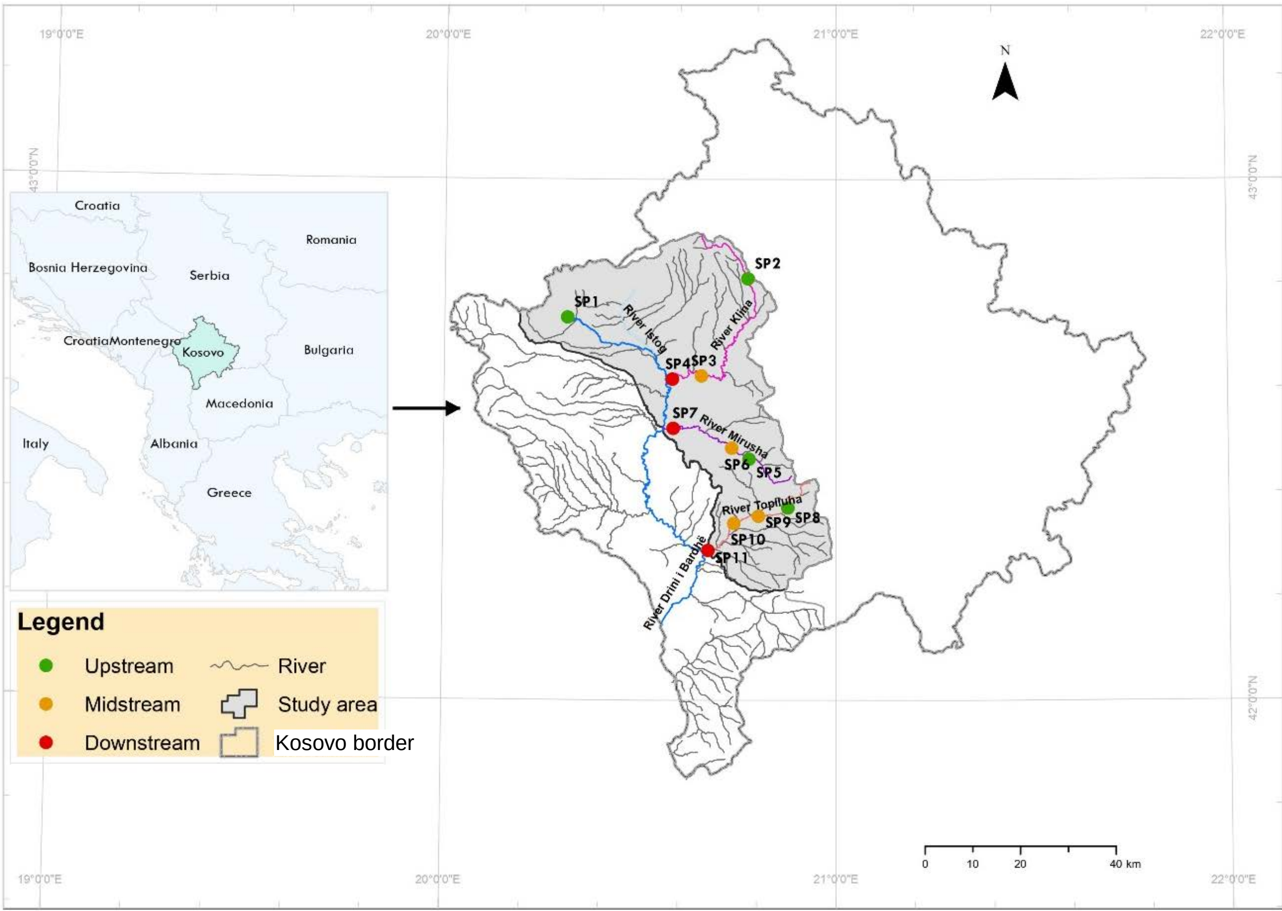

Fig. 1. The map of the study area with sampling sites; S1 – White Drin River, S2, S3, S4 – Klina; S5, S6, S7 – Mirusha; S8, S9, S10, S11 – Toplluha; source: own elaboration

Table 1. Sampling sites with geographic coordinates, altitude, habitat type and pollution sources

Sampling site	*X*	*Y*	Altitude (m a.s.l.)	Habitat type	Pollution source
S1 – the source of the White Drin River	42°44'16"N	20°18'35"E	539	boulder, cobble and sand	no pollution source is observed
S2 – Klina	42°83'58.15"N	20°75'82.88"E	1200	boulder, sand and silt	slight agricultural activities
S3 – Klina	42°62'15.00"N	20°68'20.90"E	597	cobble and gravel	agriculture/gravel and sand excavation
S4 – Klina	42°61'48.34"N	20°57'47.91"E	375	pebble and gravel, cement	municipal wastewaters
S5 – Mirusha	42°28'4.52"N	20°46'3.42"E	538	cobble, gravel and sand	sources of thermal waters
S6 – Mirusha	42°29'7.87"N	20°43'59.13"E	521	Cemented	municipal wastewaters
S7 – Mirusha	42°31'24.80"N	20°34'55.84"E	428	pebble, gravel and silt	agriculture/tourism
S8 – Toplluha	42°22'14.9"N	20°52'38.3"E	460	cobble, pebble and gravel	regulated river bank
S9 – Toplluha	42°21'17.47"N	20°48'18.85"E	371	cobble and gravel, silt	municipal wastewaters
S10 – Toplluha	42°20'24"N	20°44'26"E	338	cobble, gravel, silt, wooden debris, macrophyte, attached algae	agriculture
S11 – Toplluha	42°17'17.19"N	20°44'24.6"E	301	pebble, gravel, wood debris, macrophytes	agriculture

Source: own elaboration.

It should be noted that due to the anthropogenic disturbances, such as gravel excavation, abstraction of water for drinking, for irrigation of agricultural fields and regulation of riverbed from local authorities in cities Klina, Malisheva and Suhareka included in our research, the river morphology is modified and deteriorated. Due to poor waste management, the inhabitants dump solid waste on the river banks. In some places along the riverbank of the White Drin huge stocks of solid wastes are accumulated and contribute to further deterioration of water quality.

In all sampling sites riparian vegetation, although not very dense, was present, exception was site 2, one side of the river bank was open, as well as S4 and S6, where riverbed was regulated (covered with concrete) by the local authorities and riparian vegetation was moved.

Although hydrological parameters were not subject of this study, we consider that the changes in river hydrology as the result of many human interferences in riverbed, may have affected the macroinvertebrate assemblage. However, these parameters cannot be neglected in future research.

THE PHYSICAL AND CHEMICAL PARAMETERS

All water samples were analysed within 24 h after sampling. Water temperature (*WT*), pH, dissolved oxygen (*DO*), and electrical conductivity (*EC*) were measured in situ. The analyses of physical and chemical parameters are done based on the standard ISO 5667-6, which determines the principles to be applied in designing the programs in sample collection, the techniques of sample collection and the treatment of water samples from rivers and streams for the physical and chemical assessment [ISO 5667-6]. The analysis of water samples taken from the White Drin River basin is realized in the laboratory of the Hydro-Meteorological Institute of Kosovo. The water quality parameters are determined using sophisticated measuring equipment, which are contemporary and conform to international standards. The water temperature (*WT*) is measured in the morning with the device HI 98130 based on the standard of the method DIN 38404-C4, the turbidity (*TUR*) is measured with the device AQUALITIC/PC COMPACT based on the ISO 7027; the electrical conductivity (*EC*) is measured with the device (WTW 315i) based on the standard DIN EN 27888(C8) (11/1993) method; total dissolved solids (*TDS*) are measured with the device WW 315i based on the standard DIN EN 27888 (C8) (11/1993) method; the hydrogen ion concentration (pH) is measured with the device HI 98130 based on the standard DIN 38404-C5; method the dissolved oxygen (*DO*) and oxygen saturation (*OS*) are measured with the device HI 9146 based on ISO 5814:2012; the total suspended solids (*TSS*) are measured with the device AADAMLAB250 based on the standard of the method EN 872; biochemical oxygen demand (BOD_5) is measured with the device Winkler based on ISO 5815; chemical oxygen demand (*COD*) is measured with the chromate device based on ISO 15705; the total organic carbon (*TOC*) is measured with the device UV-SECOMAM based of the standard of the method DIN EN 1484 (H3); nitrates, nitrite, phosphates and total phosphorus as well as ammonium are measured with the device SECOMAM prim light based on the standard methods.

MACROINVERTEBRATE ANALYSIS

Macroinvertebrate samples were collected once per month in three seasons with Surber net of 30 × 20 cm (600 cm^2) diameter and kick net. Samples were taken from all available habitats represented with more than 5% of total habitat area on the sampling stretch with multi-habitat sampling procedure [HERING 2004]. Collected macroinvertebrates were preserved in 70% alcohol for laboratory analysis. The procedures for sorting and identification of macroinvertebrate samples are in line with the standard EN ISO 10870-2012. Macroinvertebrate specimens were identified up to the family level with adequate keys [TACHET *et al.* 2000; WARINGER, GRAF 1997].

To analyse species richness we used Shannon–Wiener index [SHANNON 1948] (Eq. 1), Margalef richness index [MARGALEF 1958] (Eq. 2), Menhinick's index [MENHINICK 1964] (Eq. 3); to measure diversity we used Simpson's diversity index [SIMPSON 1949] (Eq. 4), and for the biological status we used average score per taxon (ASPT) index [ARMITAGE *et al.* 1983; DICKENS *et al.* 2002] (Eq. 5); EPT-biotic index [SCHMIEDT *et al.* 1998] (Eq. 6); SWRC biotic index [SWRC 2007; MCGONIGLE 2000] (Eq. 7); Biological Monitoring Working Party (BMWP) index [ARMITAGE *et al.* 1983].

$$H = -(\sum(p_i \log 2 p_i) \quad (1)$$

Where: *H* = Shannon index, p_i = type participation in the sample, *s* = number of species in the sample

$$D_{Mg} = \frac{S-1}{logN} \quad (2)$$

Margalef richness index where *S* is the number of species and *N* is the total number of individuals, a higher value of Margalef index means higher richness and lower value means lower richness

$$D_{Mn} = \frac{S}{\sqrt{N}} \quad (3)$$

Menhinick's index where *S*-total number of species, and *N*-total number of individuals [

$$1 - \lambda = \sum_{i=l}^{s} p_{1^2} \quad (4)$$

Simpson's diversity index 1 – *λ* = Simpson's index, p_i = type participation in the sample, *s* = number of species in the sample

The Biological Monitoring Working Party (BMWP) index assigns scores from 1 to 10 to each macroinvertebrate taxa in the sample based on their sensitivity, with the highest scores assigned to most sensitive species to organic pollution. Values greater than 100 are associated with clean streams; while the scores of heavily polluted streams are less than 10.

Average score per taxon (ASTP) – this index gives the bio classification of water quality of a water body, based on the calculation of the average tolerance values of different families within the benthic macroinvertebrate community. The index is suitable for assessing the impact of organic pollution.

$$ASPT = \frac{BMWP \text{ score}}{Number\ of\ families} \quad (5)$$

$$\text{EPT} = \frac{(TV)d}{D} \quad (6)$$

Where: EPT = Ephemeroptera, Plecoptera, and Trichoptera index, *TV* = tolerance values for the families constituting EPT group, *d* = the density of each family; *D* = the total amount of densities.

$$\text{SWRC} = \frac{\sum(TV)d}{D} \quad (7)$$

Where: SWRC = Stroud Water Research Center index, *TV* = value of a taxon's tolerance, *d* = density of each taxon, *D* = total amount of density.

Values of studied indices according to corresponding water quality bio classification categories are shown in Table 2.

Table 2. Value of Ephemeroptera, Plecoptera, and Trichoptera index (EPT), Stroud Water Research Center index (SWRC), average score per taxon index (ASPT) and Biological Monitoring Working Party index (BMWP) according to corresponding water quality bio classification categories

No. family EPT-richness	<2	2–5	6–10	>10	
Water quality	poor	clean	good	excellent	
SWRC index	6.6–10.0	5.1–6.5	3.76–5.0	<3.75	
Water quality	poor	fair	good	excellent	
ASPT index	>6	5–6	4–5	<4	
Water quality	clean	partially clean	moderate impact	with impact	
BMWP index	0–10	11–40	41–70	71–100	>100
Water quality	very poor	poor	moderate	good	very good
Interpretation	heavily polluted	polluted or impacted	moderately impacted	clean but slightly impacted	unpolluted, unimpacted

Source: own elaboration based on: BODE *et al.* [1996; 1997], MCGONIGLE [2000], SWRC [2007], and FRIEDRICH [1995].

STATISTICAL ANALYSES

Pearson bivariate correlation analysis were used to measure correlation between physical and chemical parameters of water and biotic as well as diversity indices. Statistical analysis was performed with SPSS (Statistical Product and Service Solutions) software and Excel. The values of physical and chemical parameters are presented as mean value and standard deviation (*SD*). Canonical correspondence analysis (CCA) in Excel using the XLSTAT statistical software was used to show the relation of the environmental variables with biotic and diversity indices.

RESULTS AND DISCUSSION

PHYSICO-CHEMICAL PARAMETERS OF WATER

The values of measured physical and chemical parameters of water are presented in Table 3.

Table 3. Results of the water analysis during the study for month period presented as mean ± *SD* values

Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
WT (°C) Min–max	9.1±0.43 8.5–9.7	11.2±2.88 8.3–16.2	18.5±1.2 16.5–20.1	20±2.14 16–22.3	20.42±2.45 18–24.5	11.32±2.97 8.5–15.5	9.15±2.89 6.5–13.2	16.6±1.97 14.5–18.4	19.2±1.5 17.6–20.6	20.2±0.95 19.3–21.2	21.4±1.31 20.2–22.8
pH Min–max	9.8±0.06 9.7–9.8	7.89±0.17 7.8–8.2	7.63±0.11 7.6–7.89	8.09±0.09 7.9–8.2	7.21±0.05 7.15–7.29	8.36±0.28 7.99–8.63	7.8±0.3 7.46–8.11	8.72±0.20 8.49–8.83	8.2±0.18 8–8.35	8.21±0.17 8.02–8.33	8.86±0.27 8.55–9.08
TUR (NTU) Min–max	2±0.98 2–5	3.81±0.43 3.4–4.5	23.5±4.5 18–30	33.4±6.43 20–42	2.65±0.5 2.1– 3.3	21.92±7.16 13.4–28.2	14.47±7.39 7.2–24.1	4.6±1.05 3.8–5.8	38.13±10.5 27.5–48.6	35.4±9.3 29.6–46.2	56.5±41 15.8–98.1
EC ($\mu S \cdot cm^{-1}$) Min–max	135±46.8 45.6–180	370±7.1 360–380	670±43.03 600–720	740±61.7 600–805	585.25±76.0 501–660	559±83.69 468–635	493±100 400–590	443±14.7 427–220	516.6±32.5 480–542	609.3±27.02 583–637	488.6±29.6 455–511
TSS ($mg \cdot dm^{-3}$) Min–max	30.9±10.9 20.1–42	63.2±3.7 60–70	82±11.8 65–96	215±23.6 170–250	293.25±38.4 251–332	291.75±36.1 239–318	248.5±52.6 206–298	213.3±7.6 205–220	249.6±15.6 232–262	298±13 283–306	236.6±14.7 220–248
DO ($mg \cdot dm^{-3}$) Min–max	8.32±0.97 7.37–10.2	7.81±0.82 6.9–9.1	6.92±0.33 6.42–7.2	3.1±1.63 1–5	8.25±0.22 8.5–9	6.62±0.34 6.3–7.1	9.62±0.74 8.7–10.5	6.7±1.46 5.43–8.3	3.34±1.03 2.34–4.4	4.66±1.31 3.14–5.44	7.1±1.63 5.23–8.2
OS (%) Min–max	78.4±7.43 60.8–80.1	74.6±10.5 61–85	67.1±6.48 63–82	36.8±4.32 30–41	96.19±4.53 89.76–99.7	61.07±3.26 58.88–65.8	88.12±6.13 79.74–94.42	82.9±12.86 69.4–95	44.83±14.4 33.4–61.1	62.1±15.6 45.6–76.7	97.8±17.1 79.7–113.9
TDS ($mg \cdot dm^{-3}$) Min–max	4.2±1.98 2.3–6.1	11.4±3.16 7–15	20.1±4.31 16–26	48.7±6.15 41–60	0.55±0.35 <0.1–0.8	31.05±16.34 19.8–55.2	17.9±12.02 8.9–35.5	5.93±5.96 1.1–12.6	56.8±8.41 47.5–63.9	46.7±14 32.6–60.6	56.5±19.8 34.5–73.1
COD ($mg \cdot dm^{-3}$) Min–max	4.3±0.64 3.2–5	4.1±0.7 3–5	32.1±8.11 20–45	52.1±7.67 40–61	5.22±3.29 1.8–8.7	56.65±26.04 28.6–80	29.12±20.7 12–49.5	2.56±0.72 2.1–3.4	67.8±30 38.5–98.6	48.5±21.94 25.8–69.6	49.7±20.4 27.3–67.3
BOD ($mg \cdot dm^{-3}$) Min–max	1.03±0.53 0.3–1.5	3.28±1.88 0.6–5.2	6.52±0.77 6–8	4.52±0.82 3.8–6.2	2.88±1.74 0.95–4.6	17.95±14.47 1.89–37	11.77±8.44 5.55–23.53	1.36±0.5 0.9–1.4	35.06±13.5 20.4–47.2	28.63±0.9 14.8–40.5	25.8±12.3 15.3–39.4
TOC ($mg \cdot dm^{-3}$) Min–max	10.1±1.25 8–11.3	6.1±1.58 4–8	8.2±1.3 6–9	8.09±3.17 5–14	1.57±1.02 0.53–2.7	16.95±7.41 8.41–23.53	6.84±4.65 3.09–13.09	0.96±0.4 0.6–1.4	19.7±6.98 13.5–27.3	14.5±5.67 8.2–19.2	14.5±4.48 9.6–18.4
DET ($mg \cdot dm^{-3}$) Min–max	<0.01 0000	<0.01	<0.01	<0.01	<0.01	0.25±0.12 <0.1–0.4	0.11±0.02 <0.1–0.15	<0.01	0.23±0.05 0.2–0.3	<0.01	<0.01
NO_3^- ($mg \cdot dm^{-3}$) Min–max	0.5±0.4 0–1	1.2±0.49 0.6–1.8	3.9±0.5 3–4	5.2±0.64 5–6.3	5.55±0.59 4.8–6.2	8.57±3.92 15.4–14.1	5.82±1.23 4.5–7.3	3.9±1.15 3–5.2	7.43±3.28 3.7–9.9	11.2±3.99 7.8–15.6	10.4±2.58 8.1–13.2
NO_2^- ($mg \cdot dm^{-3}$) Min–max	0.21±0.01 0.18–0.22	0.05±0.02 0.01–0.09	0.08±0.013 0.06–0.1	0.07±0.01 0.06–0.09	0.01±0 0.01	0.29±0.04 0.24–0.33	0.19±0.02 0.17–0.23	0.019±0.01 0.009–0.036	0.54±0.12 0.42–0.68	0.27±0.2 0.5–0.22	0.33±0.21 0.13–0.55
TN ($mg \cdot dm^{-3}$) Min–max	1.0±0.42 0.5–1.3	1.03±0.11 0.7–1.07	2.22±0.74 4.58–3.6	4.32±1.54 3–4.52	1.43±0.09 1.34–1.52	4.11±1.77 2.49–6.24	2.41±0.96 1.55–3.28	1.06±0.26 0.8–1.32	4.52±0.65 4.07–5.28	4.44±1.05 3.67–5.64	4.65±0.75 3.81–5.24
Cl^- ($mg \cdot dm^{-3}$) Min–max	2.1±0.14 2–2.3	3.1±1.09 2–5	5.52±1.2 4–7	6.82±0.69 5.7 –7	12.2 ±1.16 10.9–13.5	19.35±2.47 15.8–21.4	15.25±1.36 13.8–16.6	2.68±1.03 2.05–3.88	6.26±0.46 5.88–6.78	4.81±0.76 4.01–5.54	4.57±0.51 3.98–4.92
PO_4^{3-} ($mg \cdot dm^{-3}$) Min–max	0.04±0.005 0.03–0.06	0.002±0.007 0.01–0.003	0.015±0.003 0.014–0.01	0.17±0.04 0.1–0.2	0.06±0.067 0.02–0.16	0.51±0.31 0.32–0.98	0.19±0.08 0.12–0.28	0.1±0.01 0.09–0.12	0.33±0.06 0.27–0.34	0.22±0.025 0.19–0.29	0.24±0.04 0.22–0.3
TP ($mg \cdot dm^{-3}$) Min–max	0.21±0.02 0.18–0.24	0.04±0.02 0.01–0.07	0.92±0.1 0.78–1.1	0.091±0.03 0.05–0.18	0.16±0.11 0.06–0.3	1.75±0.79 0.91–2.56	0.88±0.58 0.33–1.47	0.073±0.01 0.06–0.09	1.09±0.36 0.7–1.43	0.87±0.34 0.51–1.2	0.8±0.3 0.53–1.18
NH_4^+ ($mg \cdot dm^{-3}$) Min–max	0.82±0.01 0.79–0.83	0.89±0.11 0.70–0.98	1.33±0.18 1.2–1.45	3.99±0.89 2–5	0.006±0.001 0.005–0.009	0.27±0.14 0.098–0.39	0.10±0.039 0.056–0.14	0.16±0.08 0.10–0.25	2.33± 2.1–2.77	1.32±0.49 0.99–1.89	1.25±0.68 0.71–1.18
SO_4^{2-} ($mg \cdot dm^{-3}$) Min–max	2±1 1–3	2.09±0.27 1.89–2.58	3.11±0.6 2.1–4.2	11.5±0.60 10–12	4.96±0.39 4.45–5.37	12.2±4.82 9.12–18.6	9.22±2.72 7.23–13.08	11.43±3.92 8.2–15.8	17.9±3.96 14.6–22.3	18.6±3.14 15–20.5	18.2±3.05 15.2–21.3

Explanations: *WT* = water temperature, *TUR* = turbidity, *EC* = electrical conductivity, *TSS* = total suspended solids, *DO* = dissolved oxygen, *OS* = oxygen saturation, *TDS* = total dissolved solids, *COD* = chemical oxygen demand, *BOD* = biochemical oxygen demand, *TOC* = total organic carbon, *DET* = detergents, NO_3^- = nitrates, NO_2^- = nitrites, TN = total nitrogen, Cl^- = chlorides, PO_4^{3-} = phosphates, TP = total phosphorus, NH_4^+ = ammonium, SO_4^{2-} = sulphates.
Source: own study.

Water temperature (*WT*) is an important factor that affects the chemical, biochemical and biological characteristics of waters. *WT* affects distribution, health and survival of aquatic organisms [OSMAN 2010]. The range of *WT* in our samples varied from 9.1°C in S1 to 21.4°C in S11. The average value with standard deviation recorded for the three seasons was 16.09±4.89°C. As our results show, *WT* has an increasing trend going downstream the river. The temperature variation in our research is in line with results of other authors [DALLAS 2007; WARD 1992] which concluded that at a river scale, temperature variation occurs longitudinally down a river system with headwaters typically cooler than lowland areas. According to these authors, the maximum temperatures increase downstream, while the maximum range is often found in the middle reaches.

The acidity or alkalinity of water is indicated by pH. This parameter is very important because it affects the solubility and availability of nutrients and their utilization by aquatic organisms [OSMAN 2010]. The neutral to slightly alkaline pH, probably is related to carbonate nature of the sediment [BARAKAT *et al*. 2012]. The variation of pH ranged from 7.63 in S3 to 9.8 in S1. The average value with standard deviation for the three seasons for pH has been 8.25±0.69.

Turbidity (*TUR*) value has shown the variation from 2 mg·dm^{-3} in S1 up to 56.5 mg·dm^{-3} in S11. The average value with standard deviation for the three seasons is 21.4±17.9 mg·dm^{-3}. The highest *TUR* in our research is registered in S11 where the main pollution source is agriculture, which is considered as one of the main sources of stream sedimentation and turbidity [HENLEY *et al*. 2000]. Among the causes for habitat degradation, sedimentation and turbidity are identified as important contributors to declines in aquatic faunas [RICHTER *et al.* 1997].

Electrical conductivity (*EC*) is the measure of capacity of a substance or solution to conduct electric current and is used to determine the total dissolved solids in water. The World Health Organization (WHO) limit for *EC* for drinking and potable water is 700 μS·cm^{-1}. The lowest value, 135 μS·cm^{-1} was recorded in S1, whereas the highest was in S4, 740 μS·cm^{-1}. The average value with standard deviation for the three seasons is 509.9±161.8 μS·cm^{-1}. The sampling site S4 is downstream the sub-basin, Klina, respectively in the city Klina, which is characterized with decrease in species number/richness and dominance of semi sensitive organisms.

Total suspended solid (*TSS*) has been from 30.9 mg·dm^{-3} in S1 up to 298 mg·dm^{-3} in S10. The average value with standard deviation for the three seasons for *TSS* was 202±97.1 mg·dm^{-3}. In a similar research in Malaysia [AZRINA *et al.* 2006] *TSS* and *EC* were identified as two physical and chemical parameters altering the benthic macroinvertebrate community in the Langat River.

Dissolved oxygen (*DO*) ranged from 3.1 mg·dm^{-3} in S4 up to 9.62 mg·dm^{-3} in S7. The average value with standard deviation for the three seasons for *DO* has been 6.5±2.08mg·dm^{-3}. The only locality with lower *DO* than 4 mg·dm^{-3}, which can affect the aquatic life, was S4. Low *DO* in this site can be explained as a result of high radiation of this site due to regulated riverbed and total lack of riparian vegetation.

Oxygen saturation (*OS*) variation has been from 36.8% in S4 up to 97.8% in S11. The average value with standard deviation for *OS* has been 71.8±19.73%.

The chemical oxygen demand (*COD*) shows the presence of the organic substances in the water. The value of *COD* has been from 2.56 mg·dm^{-3} in S8 to 67.8 mg·dm^{-3} in S9. The average value with standard deviation for the *COD* has been 32.01±24.5 mg·dm^{-3}.

The values of *BOD* ranged from 1.03 mg·dm^{-3} in S1, indicating no presence of organic pollution in this part of the river, up to 35.06 mg·dm^{-3} in S9. The average value with standard deviation for the *BOD* has been 12.61±12.2 mg·dm^{-3}.

The total organic carbon (*TOC*), the presence of organic matter can influence the accumulation of heavy metals in the sediments [MOHIUDDIN *et al*. 2010]. The variation of *TOC* has been from 0.96 mg·dm^{-3} in S8 to 19.7 mg·dm^{-3} in S9. The average value with standard deviation for the *TOC* has been 9.77±6.05 mg·dm^{-3}.

Nitrates (NO_3^-) present the final product of the biological oxidation of the organic pollution. This shows that the water has been polluted earlier. The value of NO_3^- varied from 0.5 mg·dm^{-3} in S1 to 10.4 mg·dm^{-3} in S11. The average value with standard deviation for the NO_3^- has been 5.78±3.42 mg·dm^{-3}. There is also a trend of water quality deterioration in the direction downstream of the river.

Phosphates (PO_4^{3-}) is an element of vital importance. In the water this element is mainly found in the form of phosphates. Waters receiving raw or treated sewage, agricultural drainage, and certain industrial waters normally contain significant concentrations of phosphate. The variation of PO_4^{3-} was from 0.002 mg·dm^{-3} at S2 up to 0.51 mg·dm^{-3} at S6. The average value with standard deviation for PO_4^{3-} was 0.16±0.15 mg·dm^{-3}.

Ammonium ion (NH_4^+) the water soluble ammonia gets transformed into ammonia ion. The variation of NH_4^+ was from 0.006 mg·dm^{-3} in S6 up to 1.25 mg·dm^{-3} in S11. The average value with standard deviation for NH_4^+ has been 1.13±1.17 mg·dm^{-3}.

Nitrites (NO_2^-) are toxic and their amount in river waters is maximally limited to 0.3 mg·dm^{-3} nitrites as nitrogen. The variation of NO_2^- was from 0.01 mg·dm^{-3} in S5 up to 0.33 mg·dm^{-3} at S11. The average value with standard deviation for NO_2^- has been 0.18±0.16 mg·dm^{-3}.

Total phosphorus (TP*)* is an essential element for the growth of the living beings and can be a nutrient which limits the primary productivity of the water communities. The variation of TP has been from 0.04 mg·dm^{-3} at S4 up to 1.75 mg·dm^{-3} in S7. The average value with standard deviation for *TP* has been 0.62±0.55 mg·dm^{-3}.

The amount of sulphates (SO_4^{2-}) in the White Drin River ranged from 2 mg·dm^{-3} in S1 up to 18.6 mg·dm^{-3} in S10. The average value with standard deviation for SO_4^{2-} has been 8.77±6.36 mg·dm^{-3}.

Chlorides (Cl^-) make up the largest part of the natural water anions that can arrive as pollution through sanitary and industrial waters. The variation of Cl^- was from 2.1 mg·dm^{-3} in S1 up to 19.35 mg·dm^{-3} in S6. The average value with standard deviation for the Cl^- was 7.51±5.62 mg·dm^{-3}.

The total nitrogen (TN) value has been from 1 mg·dm^{-3} in S1 up to 4.65 mg·dm^{-3} at S11. The average value with standard deviation for TN has been 2.83±1.57 mg·dm^{-3}. Our results show that the higher concentration of nutrients were registered in river parts polluted by untreated municipal wastewaters and agricultural run off (S7 and S11). Similar studies in rivers in Europe, concluded that although there is an improvement in wastewater treatment from industrial and municipal sources in Europe, phosphorus and nitrogen remain of concern for river managers especially in regions where intensive urban or agricultural land use results in pollution of aquatic systems through diffuse nutrient inputs [KROISS *et al*. 2005].

MACROINVERTEBRATE ASSEMBLAGE AND BIOTIC INDICES

At the eleven sampling sites we collected 5946 macroinvertebrate organisms belonging to animal groups: Insects, Crustacea, Annelida, Mollusca and Turbelaria. The study of samples resulted in a total number of 51 families and 12 orders of benthic macroinvertebrates (Tab. 4). Among 5946 collected macroinvertebrates in White Drin River basin, 4307 specimens are Insects, which in taxonomic terms belong to 41 families and make up 72.28% of all sampled organisms during our study. The Amphipoda crustaceans compose other 25.39% of macroinvertebrate assemblage and the rest 2.33% is composed from Annelide worms and Mollusks.

Amphipoda crustaceans were fully dominated by family Gammaridae which consisted 99.78% of this group.

Insect class is the largest group in running water ecosystems. In respect to both diversity and abundance, this group is represented at high levels compared to other groups [HYNES 1970]. They dominated in our research throughout the sampling period, especially with the higher abundance were families Simuliidae (Diptera) with 2156 individuals (36.25% of total number of macroinvertebrates), followed by Baetidae with 758 individuals. The dominant among EPT were Ephemeroptera families with 1178 specimens, followed by Trichoptera with 277 specimens and less present were Plecoptera families with 213 specimens. Many studies in freshwater aquatic ecosystems [BERLIN, THIELE 2002; WALLIN *et al.* 2003; ROSENBERG, RESH 1993,WILLIAMS, FELTMATE 1992] have proven that the sensitive insects from the orders Ephemeroptera, Plecoptera and Trichoptera are common and well represented in taxonomic richness, diversity, and abundance in high and good quality aquatic habitats and are known as indicators of clean and oxygenated waters. As it is shown in Table 3, EPT group makes up 38.72% of all collected insects in this study. Similarly, BYTYÇI *et al*. [2018] found out that macroinvertebrate benthic community upstream in the Nerodime River in Kosovo were dominated by EPT group of insects, expressing to be good to slightly polluted water categories.

In the first sampling site (S1), upstream White Drin, macroinvertebrate fauna consisted from 30 families, which in terms of diversity represents a habitat that offers good environmental conditions for development of aquatic life. The 91.68% of the macroinvertebrate assemblage was composed of EPT taxa that indicates high water quality in this station.

The second sampling site (S2) belongs to upper stream of sub-basin Klina. It should be stated that due to the distance of this station and the mountain terrain, this locality was sampled only one month. In terms of taxa richness and abundance this site had 7 taxa (families) with 68 individuals, out of them 65 or 95.58% belonging to EPT group. Ephemeroptera families Heptagenidae and Ephemeridae were most abundant. According to the sensitivity of presented groups to pollution, 96% of organisms are sensitive to pollution and 4% semi-sensitive. In the third sampling site (S3) changes in species composition were observed, comparing to two previous sites. In terms of taxa richness and diversity, in this locality 21 taxa were recorded. Sensitive families to pollution of the Ephemeroptera and Trichoptera predominated in this locality with 65%, whereas semi sensitive species of Odonata, Coleoptera and Amphioda consisted 15% and tolerant families, Simulidae and Chironomidae (Diptera) together with Erpobdellidae and Glossiphonidae (Hirudinae) composed 20% of the macroinvertebrates. The changes in species composition in this sampling site might have occurred as a result of changes in environmental variables, increase of: *WT*, *TUR*, *EC*, *TDS* and *TSS*, and decrease of *DO*, compared to S1 and S2. As a consequence, sensitive stoneflies (Plecoptera) to high water temperature and low levels of dissolved oxygen were absent.

Going downstream the Klina River (S4), the richness and assemblage of macroinvertebrates continues to change. The number of taxa in this site comparing to S3 decreased, it was 14, but the number of organisms (abundance) increased. Semi-sensitive organisms, composed from very abundant family Gammaridae, consists 77% of the sample. The rest of the macroinvertebrate sample was made up by sensitive organisms (16%) and tolerant organisms (7%). It should be noted that in this site the value of disolved oxygen was the lowest (mean value 3.1 mg·dm^{-3}) registered during entire period of study, that have caused the replace of sensitive species with semi-sensitive and tolerant to pollution.

Sampling site S5 is located up-stream the Mirusha River and is characteristic because a source of thermal water from Malisheva thermes joins the river. The increased temperature affects the macroinvertebrate assemblage that is relatively poor, with only six families present. Ephemeroptera and Trichoptera insects are present in very small number, whereas the dominant group is Amphipoda, (Gammaridae) making up 96% of total number of organisms. Similar studies have shown that the water temperature is important for the embryonic development, larval growth, emergence, metabolism and survivorship of aquatic organisms [HAIDEKKER, HERING 2008].

The sampling site S6 is in the Mirusha River in the city of Malisheva. The riverbed is heavily modified as it is cemented and exposed to the radiation due to the lack of riparian vegetation. The river in the city receives untreated

Table 4. The distribution of macroinvertebrates in sampling sites

No.	Class/order	Family	No. of organisms in sampling site										
			S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
1	Trichoptera	Hydropsychidae	22	3	23	32	4	20	2	2	1	1	6
2		Brachycentridae	17	–	–	1	–	–	–	–	–	–	–
3		Psychomyidae	4	–	–	–	–	–	–	–	–	–	–
4		Philopotamidae	8	–	–	–	–	–	–	–	–	–	–
5		Limnephilidae	35	15	–	–	–	–	–	–	1	–	–
6		Leptoceridae	9	–	–	–	–	–	–	–	–	–	–
7		Rhyacophilidae	39	–	19	–	–	–	3	–	–	–	–
8		Lepidostomatidae	9	–	–	–	–	–	–	–	–	–	–
9		Sericostomatidae	4	–	–	–	–	–	–	–	–	–	–
10		Odontoceridae	8	–	–	–	–	–	–	–	–	–	–
11	Plecoptera	Nemouridae	55	–	–	–	–	–	–	–	–	–	–
12		Chloroperlidae	14	–	–	–	–	–	–	–	–	–	–
13		Taeniopterygidae	43	–	–	–	–	–	–	–	–	–	–
14		Capnidae	29	2	–	–	–	–	–	–	–	–	–
15		Perlidae	33	3	–	–	–	–	–	4	5		6
16		Leuctridae	10	–	–	–	–	–	–	1	–	–	–
17		Perlodidae	6	–	–	–	–	–	3	–	–	–	–
18	Ephemeroptera	Ephemeridae	12	20	61	–	–	–	–	58	–	–	1
19		Baetidae	19	–	29	65	–	251	157	82	27	100	28
20		Heptagenidae	19	20	8	16	3	–	2	7	6	–	–
21		Ephemerellidae	13	–	73	15	–	3	6	11	3	4	5
22		Leptophlebidae	1	–	–	–	–	–	–	–	–	–	–
23		Caenidae	–	–	8	3	–	–	–	1	20	–	23
24	Diptera	Blephariceidae	8	–	–	–	–	–	–	–	–	–	–
25		Simulidae	–	–	6	31	–	942	1148	3	–	26	–
26		Rhagionidae	2	–	–	–	–	–	–	–	–	–	–
27		Chironomidae	–	–	45	7	–	–	–	–	187	2	–
28		Limonnidae	3	–	–	–	–	–	–	–	–	–	–
29		Tipulidae	–	–	10	–	–	3	3	–	–	–	–
30		Tabanidae	–	–	–	–	–	–	2	–	–	–	–
31		Athericidae	–	–	–	–	–	–	–	7	–	–	–
32	Odonata	Coenagrionidae	2	–	–	–	–	–	–	–	–	–	–
33		Gomphidae	–	–	–	–	–	2	1	42	7	1	50
34		Lestidae	–	–	2	–	–	–	–	–	–	–	–
35		Calopterygidae	3	–	1	49	–	6	–	–	–	–	3
36		Libelluidae	–	–	–	–	–	2	3	–	–	–	–
37		Platycnemidae	–	–	14	15	–	–	–	–	–	–	–
38	Amphipoda	Gammaridae	13	3	30	545	539	16	60	25	–	77	99
39	Isopoda	Asellidae	–	–	–	–	3	–	–	–	–	–	–
40	Mollusca	Physidae	2	–	–	–	3	–	–	–	–	–	–
41		Lymnareidae	–	–	–	–	5	–	–	–	–	–	–
42		Valvatidae	–	–	1	–	–	–	–	–	–	–	–
43		Sphaeridae	–	–	–	3	–	–	–	–	–	–	–
44	Hirudinea	Hirudidae	3	–	–	–	–	2	1		2	17	
45		Erpopdelidae	–	–	16	4	–	19	1	–	25	24	2
46		Glossiponidae	–	–	5	–	–	–	–	–	–	–	–
47	Coleoptera	Gyrinidae	–	–	4	–	–	–	–	–	–	–	–
48		Chrysomelidae	–	–	2	–	–	–	–	–	–	–	–
49		Haliplidae	–	–	1	–	–	–	–	–	–	–	–
50	Megaloptera	Sialidae	–	–	1	–	–	–	–	–	–	–	–
51	Turbelaria	Planaridae	–	–	–	1	–	–	–	–	–	–	–
Total			445	68	414	795	557	1267	1397	244	284	252	223

Source: own study.

wastewaters from the municipality as well as waters from industries and agricultural runoff from suburban area. Obviously, these heavy polluted conditions have affected the macroinvertebrate assemblage in terms of taxa richness as well as in terms of abundance. In terms of diversity, the macroinvertebrate assemblage is made up by 11 taxa/families, dominated by highly abundant insects of the family Simulidae (Diptera) which makes up 74% of total number of specimens, followed by semi tolerant family Baetidae (20%) and less represented Hirudinea, Trichoptera, Amphipoda and Odonata.

Sampling site S7 belongs to the downstream of the river basin. As shown in Table 4 in this locality a total of 1393 individuals were collected. The largest percentage of macroinvertebrate assemblage is composed of Diptera family, with 1153 individuals or 83%, followed by semi tolerant families of Ephemeroptera with 165 individuals or 12%, Amphipoda with 60 individuals or 4%. The rest of the sample is made up from Trichoptera, 0.35%, Odonata 0.28%, Plecoptera 0.21% and Hirudinea 0.14%. In this sampling site we have a higher taxa diversity compared to the two other localities of the Mirusha River. The presence of EPT species indicates an improvement of environmental conditions which can be attributed to the increased dilution capacity after the confluence of Mirusha with the White Drin River and from other tributaries which join river in this area. The largest number/abundance had Simulidae family with 1148 individuals, which is also the most dominant in this locality.

The sampling site S8 is located at the upper site of the sub-basin (river) Toplluha. Collected macroinvertebrate specimens in this site belong to 12 different taxa. The most abundant group was Ephemeroptera with 159 individuals (65%), dominated by families Baetidae and Ephemeridae. Family Gomphidae (Odonata) with 42 individuals composed 17% and Amphipoda crustacenas 11% of macroinvertebrate assemblage. The rest of the sample consisted from Diptera, Plecoptera and Trichoptera. It can be seen that in this locality sensitive taxa to pollution were present in symbolic numbers, compared to these semi tolerant. In locality S9 the macroinvertebrate assemblage was composed from 11 taxa. The structure in this locality changed in favour of pollution tolerant taxa with predominance of tolerant family Chironomidae (Diptera) with 187 individuals or 66% and Hirudinea with 56 individuals or 9%. Ephemeroptera with semi tolerant families Baetidae and Caenidae made up made up 20%, and the rest of the macroinvertebrate community consisted from Odonata, Plecoptera and Trichoptera. The dominance of semi tolerant and tolerant macroinvertebrate taxa continues downstream the river (S10) where the macroinvertebrate community is composed from semi tolerant and tolerant groups of benthic organisms such as family Baetidae (Ephemeroptera) with 100 individuals (41%), and Gammaridae (Amphipoda) with 77 individuals (31%), Simuliidae (Diptera) with 24 individuals (10%) and Hirudinea with 41 individuals (16%).

Sampling site S11 belongs to the part where sub-basin Toplluha confluences the White Drin River. In this station 223 individuals that belong to 10 taxa/families were collected. The highest percentage of the macroinvertebrate community belongs to family Gammaridae (Amphipoda) with 99 individuals (44%), followed by insect families Baetidae and Caenidae (Ephemeroptera) with 57 individuals (25%), Gomphidae (Odonata) with 50 individuals (22.42%). This macroimnvertebrate composition where semi-sensitive taxa are dominant indicates an improvement in environmental conditions after the increase of water level and increased dilution capacities.

Our results presented in Table 5 show the scores of biotic and diversity indices and classification of water in quality classes.

The EPT and SWRC index scores in the monitoring site S1 indicate the category of "excellent" water quality. The values of BMWP and ASPT also classify water from this site at the highest category of the water, indicating "very good" and "clean" water quality. The value of the EPT index in the monitoring station S2 indicated the category of "good' quality". The SWRC score classifies the water quality in the category "excellent". The BMWP score means moderate category, while ASPT index classifies the water quality in this station in the category of "clean". The values of the EPT index in the sampling sites S3 and S4 indicate the category of "good" quality. The values of the SWRC index classify the water quality in these two sites in the category "fair". While the values of the BMWP index in sampling sites S3 and S4 indicate the water quality of the moderate category, the values of ASPT index classify these two stations in the category of "partially clean' water quality (Tab. 5).

The value of the EPT index in the sampling site S5 classifies the water quality in the category poor, whereas in S6 it is classified as "clean". BMWP score classifies the water quality in S5 and S6 as poor category, whereas according to ASPT bio-classification, S5 belongs to moderate impact water quality and S6 to partially clean. The value of the SWRC index classifies these two stations in

Table 5. Mean values of biotic and diversity indices in sampling sites in the White Drin River basin presented as mean ± standard deviation

Index	Values in sampling sites										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
BMWP	237	54	51.8±19.1	44.5±12.2	16.25±5.9	30.25±14.45	43.25±8.05	60.6±6.5	33.6±15.01	24.3±6.8	44±18.08
ASPT	7.9	7.71	5.79±1.14	5.82±0.48	4.58±0.4	5.77±1.66	6.13±0.74	7.59±0.13	5.43±1.6	5.19±0.39	7.18±0.54
SWRC	2.58	3.4	5.16±1.10	5.67±0.20	6.02±0.03	5.34±0.52	5.53±0.27	4.09±0.72	5.51±0.63	5.53±0.60	4.79±0.05
EPT	23	6	7	6	2	3	6	9	7	3	6
Shannon–Wiener diversity index (*H*)	4.36	2.22	2.20±0.63	1.52±0.58	0.22±0.12	1.08±0.57	0.94±0.19	2.11±0.54	1.45±0.64	1.5±0.3	1.78±0.43
Simpson's diversity index (*D*)	0.06	0.24	0.36±0.18	0.51±0.16	0.94±0.03	0.59±0.21	0.65±0.17	0.32±0.13	0.49±0.18	0.41±0.08	0.36±0.09
Margalef's index (*R*)	4.91	1.42	1.78±0.49	1.39±0.53	0.45±0.24	0.98±0.45	0.90±0.16	1.64±0.36	1.02±0.34	0.89±0.43	1.09±0.43
Menhinick's index	1.46	0.84	1.13±0.38	0.70±0.23	0.27±0.09	0.39±0.19	0.35±0.06	0.94±0.28	0.58±0.17	0.78±0.53	0.63±0.20

Explanations: BMWP = Biological Monitoring Working Party, ASPT = average score per taxon, SWRC = Stroud Water Research Center index.
Source: own study.

the category of fair" water quality. The value of the EPT and SWRC index in the sampling site S7 classifies the water in this site in the category "good" and 'partially clean" quality, whereas the scores of BMWP and ASPT indicate "moderate" and "clean" water quality. The score of biotic indices EPT and SWRC in the sampling sites S8 and S11 classify these two sites to the category "Good" quality, whereas the values of two other biotic indices BMWP and ASPT, indicate the moderate, clean water category respectively. The values of the EPT index in the monitoring sites S9 and S10 indicate the "good" and "clean" water quality, whereas the score of SWRC index classifies these two sites in category "partially clean". According to BMWP and ASPT water quality classification, these two sites belong to "poor" and "partially clean" water quality. Based on the scores of biotic indices, we can conclude that they confirm the qualitative aspect of the taxa richness and diversity of the studied sites, therefore they reflect the ecological status of the water bodies.

The global diversity has led to the adaptation and modification of several standard biological methods for use with enormous range of organisms [FRIEDRICH *et al.* 1984]. The average Shannon–Wiener diversity index values showed that the species diversity was highest upstream in the White Drin River (S1) where H = 4.36, and decreased in all sampling sites, reaching the lowest mean value H = 0.22 in S5 and S7, H = 0.94. WILHM and DORRIS [1968], after examining diversity in a range of polluted streams, concluded that values of Shannon–Wiener diversity index (H) < 1 indicate heavily polluted conditions, values 1–3 indicate moderately polluted, whereas values >3 indicate clean water conditions. The values of Simpson diversity index were between 0.06 and 0.94. The lowest value, meaning the highest diversity, was in S1 and the highest value, indicating the poorest diversity, was in S5. Margalef species richness index is the simplest way to measure the biodiversity. It counts the number of different species in a given area. This index varied between 4.91 and 0.45. This index also shows that alongside the river, the poorest diversity was in S5 and the richest in taxa diversity was S1, in the source area of the White Drin River (Tab. 5). The values of Menhinick's index varied between 0.27–1.46. Similarly to other diversity indices, this index shows the lowest value in S5 and the highest value in S1.

In CCA biplot (Fig. 2) we can see the relationship of environmental variables with biotic and diversity indices. Water temperature has only one significant correlation (p < 0.05) with ASPT which is negative, while the parameter pH has significant correlation with seven different indices. It has positive correlation (p < 0.01), with biotic indices BMWP, EPT and diversity indices Shannon–Wiener diversity index as well as with Margalef's index and Menhinick's index (p < 0.05), whereas it is negatively correlated to SWRC biotic index (p < 0.05) and Simpson's diversity index (p < 0.01). The parameter *TUR* has one significant correlation with ASPT index, which is negative (p < 0.01). *EC* has shown significant correlations with five different indices. It has significant negative correlation (p < 0.01) with BMWP and EPT index, and diversity indices Shannon–Wiener diversity index and Margalef's index (p < 0.05), but it has positive correlation with SWRC biotic index (p < 0.01). The parameter *TSS* has negative significant correlation with seven indices BMWP (p < 0.05), SWRC (p < 0.01), EPT (p < 0.05), Shannon–Wiener diversity index (p < 0.01), Margalef's index and Menhinick's index (p < 0.01), and it has positive correlation only with Simpson's diversity index (p < 0.01). The parameters *DO*, *OS*, *COD*, *BOD*, *TOC*, NO_2^-, PO_4^{3-}, *TP*, NH_4^+ and SO_4^{2-} have no significant correlation with any of the biotic or diversity indices. *TDS* has only one significant negative correlation, with ASPT (p < 0.05). As shown in Table 6, parameter NO_3^- has significant negative correlations with BMWP (p < 0.05), ASPT (p < 0.01), EPT (p < 0.05) and Margalef's index (p < 0.05), whereas it shows a positive correlation with SWRC (p < 0.05). The parameter TN has only one significant correlation with ASPT, which is negative (p < 0.05). The parameter Cl^- has significant negative correlations with two diversity indices: Shannon–Wiener

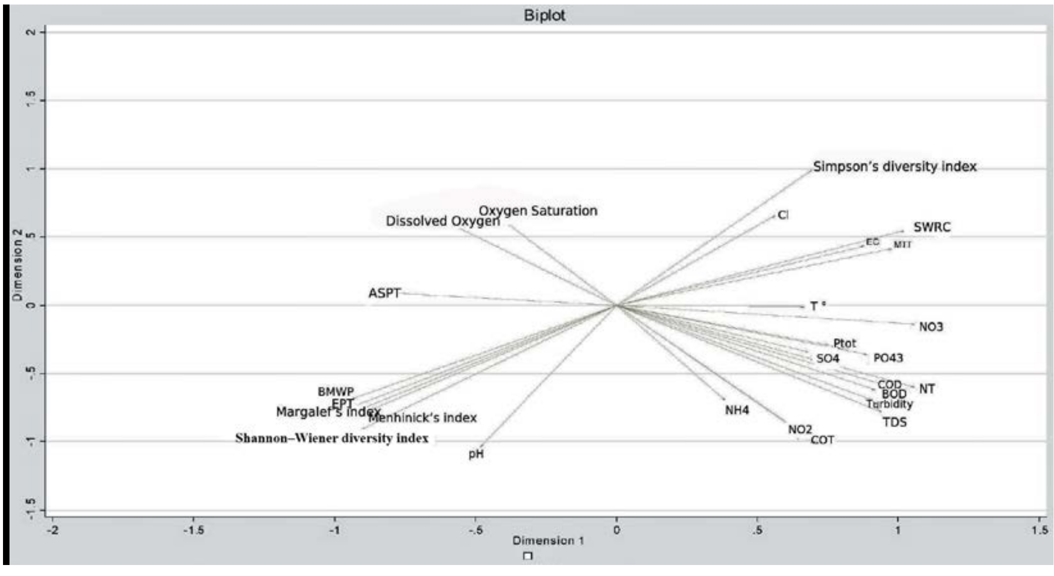

Fig. 2. Relationship between environmental variables and biotic and diversity indices acc. to canonical correspondence analysis (CCA) biplot; parameters' abbreviations as in Tab. 3; source: own study

Table 6. The Pearson's correlation between physical and chemical parameters and biotic and diversity indices

Parameter	BMWP	ASPT	SWRC	EPT	Shannon–Wiener diversity index (*H*)	Simpson's diversity index (*D*)	Margalef's index (*R*)	Menhinick's index
WT	–0.514	–0.627*	0.550	–0.458	–0.383	0.285	–0.464	–0.183
pH	0.774**	0.097	–0.701*	0.787**	0.785**	–0.735**	0.762**	0.610*
TUR	–0.378	–0.779**	0.439	–0.325	–0.214	0.010	–0.351	–0.210
EC	–0.796**	–0.373	0.872**	–0.780**	–0.713*	0.593	–0.728*	–0.496
TSS	–0.700*	–0.488	0.795**	–0.703*	–0.823**	0.745**	–0.751**	–0.819**
DO	0.295	0.113	–0.358	0.220	0.116	0.029	0.211	0.010
OS	0.113	–0.267	–0.232	0.069	–0.017	0.096	0.020	–0.088
TDS	–0.381	–0.603*	0.439	–0.324	–0.222	0.007	–0.353	–0.240
COD	–0.429	–0.502	0.587	–0.388	–0.342	0.187	–0.396	–0.360
BOD	–0.391	–0.557	0.420	–0.344	–0.294	0.101	–0.403	–0.343
TOC	–0.054	–0.365	0.166	–0.045	0.027	–0.142	–0.042	–0.087
NO_3^-	–0.609*	–0.739**	0.668*	–0.615*	–0.572	0.393	–0.625*	–0.558
NO_2^-	–0.025	–0.374	0.154	0.030	–0.005	–0.078	–0.051	–0.157
TN	–0.452	–0.629*	0.587	–0.431	–0.369	0.196	–0.434	–0.390
Cl^-	–0.415	–0.126	0.583	–0.490	–0.662*	0.740**	–0.470	–0.753**
PO_4^{3-}	–0.420	–0.355	0.483	–0.420	–0.451	0.328	–0.436	–0.571
TP	–0.315	–0.324	0.422	–0.327	–0.301	0.213	–0.303	–0.353
NH_4^+	–0.067	–0.123	0.211	–0.005	0.072	–0.145	0.005	0.133
SO_4^{2-}	–0.305	–0.507	0.301	–0.190	–0.300	0.198	–0.329	–0.431

Explanations: BMWP = Biological Monitoring Working Party, ASPT = average score per taxon, SWRC = Stroud Water Research Center, EPT = Ephemeroptera, Plecoptera, and Trichoptera, other parameters as in Tab. 2; ** correlation is significant at the 0.01 level (2-tailed), * correlation is significant at the 0.05 level (2-tailed).
Source: own study.

index ($p < 0.05$) and Menhinick's index ($p < 0.01$), whereas it has positive correlation with Simpson's diversity index ($p < 0.01$).

The changes in biotic indices as the result of fluctuations in physical and chemical characteristics of water have been reported from other authors, in Nysa Klodzka River in southern Poland, CZERNIAWSKA and KUSZA [2005] have used Spearman's correlation coefficient to analyse correlation between biotic and diversity indices of benthic macroinvertebrates with physical and chemical variables; DUKA *et al*. [2017] studied benthic macroinvertebrates in the Osumi, Devolli, and Shkumbini Rivers in Albania in relationship between EPT species richness index and chemical parameters of water. A negative correlation between EPT taxa and increased nutrient concentration in water was reported in a study in coastal tropical streams in Ecuador [MARTÍNEZ-SANZ *et al*. 2014]. WANG [2014] found a relationship between conductivity and benthic macroinvertebrate communities to be related to contamination sources such as urban runoff, sewage outfalls and effluent from point sources. Another author (YAP *et al*. [2006] has shown the variation in distribution of a benthic Oligochaeta species (*Limnodrilus sp*.) in relation to physical and chemical parameters of water in a river in Malaysia, and found out that the distribution of *Limnodrilus sp*. was in positive correlation with *BOD*, NO_3^-, NH_4^+, *TSS*, *COD* and concentrations of Cu and Zn in the water, but was negatively correlated with pH and *DO*. Our results were similar to those of BYTYQI *et al*. [2019] and BAJRAKTARI *et al*. [2019], where pH ranged from 6.9 to 8.7, nitrates-N < 8.57 mg·dm^{-3}.

According to BAJRAKTARI *et al*. [2019] variation of the ammonium-N were from 0.37 to 14.97 mg·dm^{-3} and phosphate was from 0.06 to 4.07 mg·dm^{-3}. ALAVAISHA *et al*. [2019] studied the correlation between diversity indices and ASPT of benthic macroinvertebrate's communities with physical and chemical parameters of water across irrigation schemes in a case study in Tanzania and showed that diversity index and ASPT were negatively correlated with dissolved oxygen (*DO*), and positively with turbidity and electrical conductivity. NH_4^+ was negatively correlated with Margalef richness index, Simpson's diversity index and ASPT, whereas PO_4^{3-} was not correlated with any of the indices. As seen in our results, Diptera (42.28%), Amphipoda (25.39%) and Ephemeroptera (19.8%) dominated the study area, accounting for more than 85.68% of all macroinvertebrate taxa. These taxa have a potential for biomonitoring, as their fluctuation can be related to human impacts [BONADA *et al.* 2006]. Such research studies have been recorded in similar studies: the Nysa Klodzka River (Poland) [CZERNIAWSKA-KUSZA 2005], Değirmendere Stream (Isparta, Turkey) [ZEYBEK *et al*. 2014]. In our study, Plecoptera, Trichoptera, Ephemeroptera and Odonata were dominant upstream in localities S1, S2, and S8, indicating good water quality. The decrease in number of EPT taxa in sampling sites S5–S9 and S11, as well the total lack of sensitive Plecoptera in sampling sites S3, S4, S5 and S6, indicates the deterioration of water quality. These changes occurred as a result of discharged waste waters, agricultural runoff, modification of riverbed and water abstraction for irrigation purposes. The changes in river type, position and structure of the riverbed corresponds with changes in macroinvertebrate assemblage, as it is reflected in sites S3, S4, S6, S7 and S10, where the semi tolerant taxa of Ephemeroptera, Diptera (Simuliidae) and Chironomide, common in mid and downstream of the rivers, were dominant, indicating pollution level. The presence of semi-tolerant and tolerant taxa in a sample indicates the environmental conditions – the presence of pollution which is reflected in the values of environmental variables. As seen from our results in Table 5, among nutrients, nitrates (NO_3^-) is the parameter that affects negatively the biotic indices BMWP, EPT, ASPT and Margalef's index. Nutrient enrichment in S10 and S11 (Tab. 2) due to the organic pollution by agricultural runoff resulted with elimination of sensitive taxa and the dominance of semi sensitive and tolerant taxa in this two sampling sites. Apart from this, the recorded taxa/families Baetidae and Caenidae in sampling sites mid-stream and downstream (S3, S4, S6, S7, S8, S9, S10 and S11) can be considered as representative characteristic for mid and down stretch of the rivers [VILDINOVA *et al.* 2006].

CONCLUSIONS

Based on our results we can conclude that human activities in three sub-basins of the White Drin have strong impact in water physical and chemical parameters which affect macroinvertebrate assemblage. This is well documented with changes in macroinvertebrate distribution and diversity and in the values of biotic and diversity indices in three sub-basins as well as in the mainstream of the White Drin River basin. Upper sites were characterized with rich diversity with presence of sensitive EPT species to low oxygen concentration and high water temperature, indicating good, undisturbed environmental conditions. In other hand, the presence of the pollution tolerant organisms in the middle and downstream sampling sites indicated presence of non-point sources of pollution discharge due to human activities which caused the water quality deterioration. We concluded that the main pollution sources in the White Drin River basin are agriculture and untreated municipal wastewaters, followed by industry and sand excavation.

The Pearson's correlation coefficient and CCA has shown that the water parameters with high impact in biotic and diversity indices are water temperature, electrical conductivity, total suspended solids, NO_3 and Cl. The most sensitive biotic indices are Biological Monitoring Working Party (BMWP), Ephemeroptera, Plecoptera, and Trichoptera (EPT) and average score per taxon (ASPT) whereas Stround Water Research Center (SWRC) was not negatively correlated to any of the parameters. Among diversity indices: Shannon–Wiener index, Menhinick's index and Mergalef's index have negative correlation with above mentioned physical and chemical water parameters, whereas Simpson's index showed positive correlation with most of these parameters. The biotic and diversity indices classify water of the White Drin sub-basins in different quality categories (I–IV), indicating the changes throughout their courses.

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