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# Investigation of benthic macroinvertable fauna and some environmental variables in Sızır Waterfall (Gemerek-Sivas)

**Menekşe TAŞ-DİVRİK**[1], **Belgin ÇAMUR-ELİPEK**[2], **Burak ÖTERLER**[2], **Pınar ALTINOLUK-MİMİROĞLU**[3]

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[1] Sivas Cumhuriyet University, Şarkışla Aşık Veysel Vocational School, Şarkışla, 58400, Sivas, Türkiye

[2] Trakya University, Faculty of Science, Department of Biology, Hydrobiology Section, 22030, Edirne, Türkiye

[3] Trakya University, TUTAGEM Research Center, 22030, Edirne, Türkiye

**ORCID IDs of the author(s):**

M.T.D. 0000-0002-4828-2575
B.Ç.E. 0000-0002-0954-8967
B.Ö. 0000-0002-9064-1666
P.A.M. 0000-0002-8524-0972

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**Correspondence:**
**Menekşe TAŞ-DİVRİK**
**E-mail:** menekse.tas@cumhuriyet.edu.tr



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## ABSTRACT

In this study, the benthic macroinvertebrate fauna of Sızır Waterfall, which is located in Sivas Province (Türkiye) and has an important place in recreational activities, and some environmental variables (velocity speed, water temperature, pH, conductivity, dissolved oxygen, total hardness of water, Ca, Mg, Cl, salinity, total amount of dissolved matter, $PO_4$, $SO_4$, $NO_2$-N, $NO_3$-N contents) that may be effective in their distribution were investigated. Also, some elements (Li, B, Na, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Cd, Sb, Ba, Tl, Pb) and a total of 181 types of pesticides were investigated in the studied area. During the wet and dry seasons of 2022, samplings were made from a total of 3 stations: at the beginning of the waterfall (upstream), inside the waterfall (waterfall) and at the exit of the waterfall (downstream). While individuals belonging to Oligochaeta (*Potamothrix* sp.), Gastropoda (*Physa* sp.), Amphipoda (*Gammarus pseudosyriacus*), Ephemeroptera (*Baetis* sp.), Plecoptera, Trichoptera, Coleoptera, Diptera and Odonata were determined. Also the physicochemical analysis results were evaluated in terms of water quality. The physicochemical and biological data of the sampling stations were examined statistically, and based on the similarity obtained, the effects of environmental variables on the distribution of macroinvertebrates were evaluated. The relationship between physicochemical data was analyzed using Pearson Correlation Analysis.

**Keywords:** Waterfall, Running water, Water quality, Benthic macroinvertebrate, Similarity

## Introduction

Waterfalls are morphological formations occurring in slope breaks that may be present along stream beds. These formations, with different shapes and sizes, can differ from each other in terms of their ecological characteristics and biological content.

Aquatic environments must maintain healthy ecological conditions by balancing their physical, chemical, and biological components. Water quality consists of a set of parameters or variables that describe a water body's physical and chemical properties and biological components, which sustain various uses or processes. (Hussen et al., 2018).

Waterfalls are often overlooked in inland water studies because they give the impression of a lifeless area due to the pressure created by gravity (Hussen et al., 2018). For this reason, research on waterfall systems is generally limited to examining their hydrological and geological features regarding their ecotourism potential and their use for drinking and irrigation water purposes (Hussen et al., 2018). However, as an aquatic ecosystem, waterfalls have various functions such as providing clean water, controlling pollution, and supplying some critical chemicals to the ecosystem (Hussen et al., 2018). In nature-based tourism activities, habitat destruction and pollution elements entering the ecosystem damage the natural ecosystem and biodiversity. Therefore, evaluating biological elements and physical and chemical parameters in aquatic ecosystems is important. In addition to the effects of anthropogenic activities, it is reported that climate change and soil type characterised by wet/dry seasons also affect water quality (Hussen et al., 2018). Additionally, any change in physical and chemical parameters in aquatic ecosystems can affect aquatic biota in various ways.

Studies on the water quality of waterfalls and benthic macroinvertebrate groups are also included in limnological research. Nyamangara et al. (2008) investigated some heavy metals in water and sediment samples taken from a waterfall in Zimbabwe, while Hussen et al. (2018) examined physical and chemical parameters in water samples taken from a waterfall in Indonesia from three locations (upstream, waterfall, and downstream) during the wet season. In the previous studies performed in Türkiye, Çağlar & Saler (2014) examined the water quality of Koçan Waterfall and Saplıoğlu et al. (2017) evaluated the water quality of Karpuz Stream, Düden Stream and Kurşunlu Waterfall.

In addition to taxonomic studies investigating benthic macroinvertebrate groups in waterfalls, there are also studies evaluating the regional distributions of these groups and ecological factors that may be effective in their distribution (Sites & Vitheepradit, 2007; Gregoric et al., 2010; Sites et al., 2011; Prommi et al., 2012; Rackemann et al., 2013; Sharifah Aisyah et al., 2015; Clayton & Pearson, 2016; Tavares et al., 1998; Baker et al., 2017; Andrade et al., 2020; Thamsenanupap et al., 2021; Mello & Abessa, 2021; Zakiah et al., 2022). Findings of benthic macroinvertebrate groups are also reported in the studies conducted in some waterfalls in Türkiye. In the study carried out by Kum (2018) in Ilıca Waterfall (Kastamonu), members belonging to the Trichoptera group, one of the benthic macroinvertebrates, were recorded, while Demir (2020) reported the findings obtained from waterfalls in the Black Sea and Mediterranean Regions.

Sızır Waterfall, which is the study area, was declared a second-degree natural protected area by the Sivas Regional Directorate for the Protection of Cultural and Natural Heritage in 2001. There are two studies performed in the previous study area: one of these was published with the title "Hydrogeological and hydrogeochemical properties of the Sızır Springs aquifer" by Aydın & Ekmekçi (2005) and the other with the title "Recreational potential of Sızır Waterfall and its surroundings within the scope of sustainability" by Karadeniz (2013). Also, Aydın & Ekmekçi (2005) presented a study that included data on some chemical analyses from the studied area. Up to now, no study has evaluated the physicochemical and biological properties of Sızır Waterfall together.

## Materials and Methods

The Sızır Waterfall is situated between 39°18' north latitude and 35°56' east longitude, within the borders of the Sızır town in the Gemerek (39º11′ N, 36º04′ E) district of Sivas province, located in the Upper Kızılırmak Section of the Central Anatolia Region of Türkiye (Karadeniz, 2013). The waterfall was formed by the pouring of the Göksu Stream (also known as Sızır Suyu), a tributary of the Kızılırmak River, over travertine steps. The height of the waterfall varies according to seasonal water flow, with water falling from approximately 22 meters at peak capacity (Karadeniz, 2013). Some of the waters coming out of the springs (Ayanözü Stream formed by the merger of Çatalkaya, Bağırsak, Kurudere and Erikli streams and Kırkgöz waters coming out of the karstic springs in the town of Sızır) that come out of Akdağ and feed Göksu Stream are transferred to Sızır Dam, while some flow by forming the Sızır Waterfall and mix with the Kızılırmak River (İzbırak, 1971; Saraçoğlu, 1990). It is reported that the flow rate of Sızır Waterfall is the highest in the spring season due to increased precipitation and melting snow. The flow rate is the lowest in the summer due to drought, the amount of water supplied to the dam, and the use of agricultural irrigation water (Karadeniz, 2013).

In the study area, water and sediment samples were taken from a total of 3 stations (upstream, waterfall, downstream) in the wet season (May 2022) and dry season (August 2022). The sampling periods were determined by taking into account the seasonal characteristics of the waterfall according to the literature. The location called "upstream", where the waterfall's water first comes out, was chosen as station number 1, while the location called “waterfall”, where the waterfall falls, was chosen as station number 2, and the location called “downstream”, the part just before where the waterfall merges with the Kızılırmak River was determined as station number 3. The locations of the waterfall and sampling stations are shown in Figure 1. The coordinates and bottom structures of the sampling stations are given in Table 1.

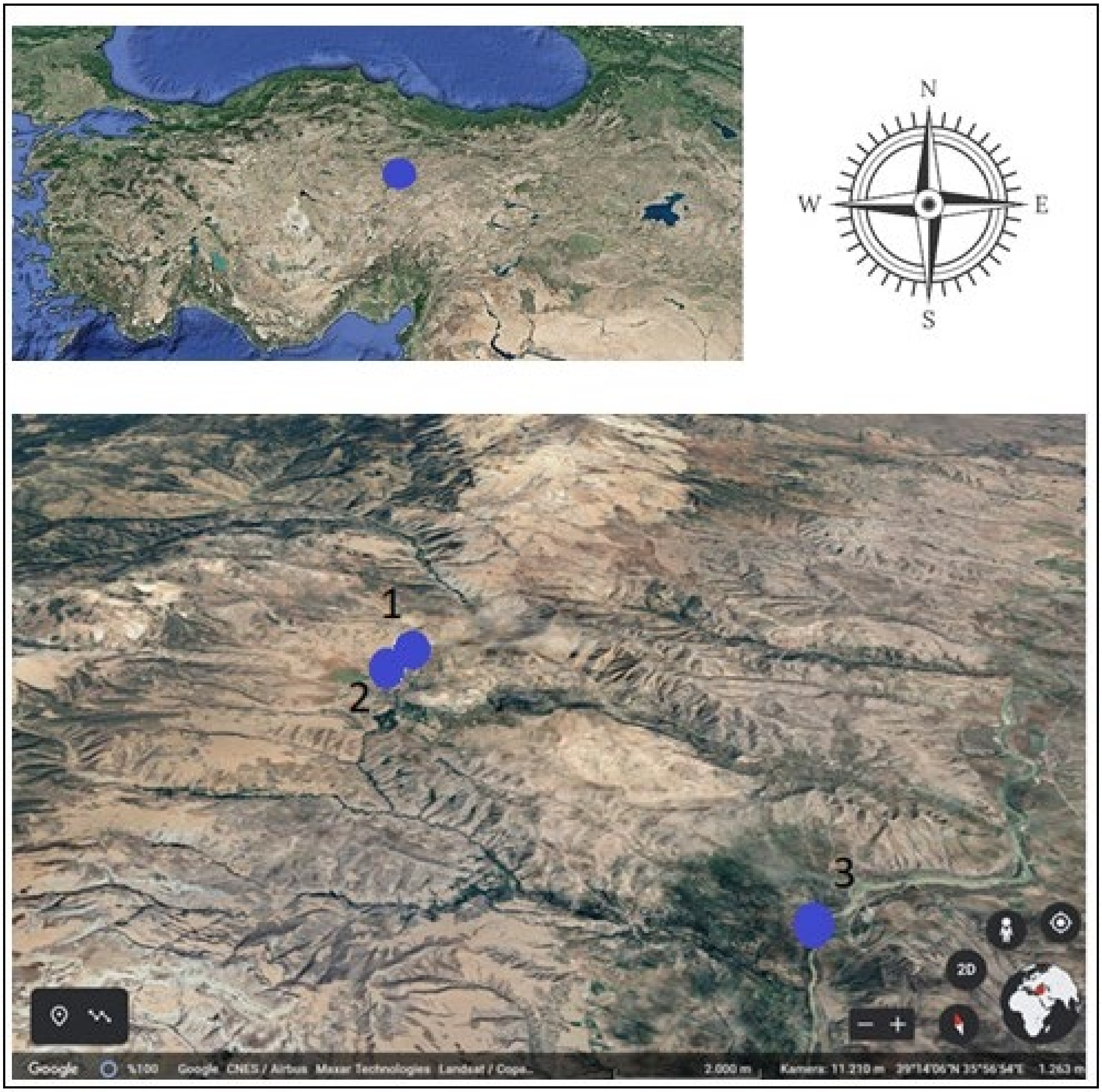


**Figure 1.** Location of Sızır Waterfall and the sampling stations

**Table 1.** The coordinates of the sampling stations and their bottom structures

| Stations | Coordinates | Locations | Bottom structures |
|---|---|---|---|
| St. 1 (upstream) | 39°18′47″ N<br>35°57′13″ E | Kalebaşı, Sızır / Gemerek | Pebbles, secondary aquatic plants |
| St. 2 (waterfall) | 39°18′19″ N<br>35°56′49″ E | Köprübaşı, Sızır / Gemerek | Pebbles |
| St. 3 (downstream) | 39°13′03″ N<br>35º59′14″ E | Tekmen village, Gemerek | Pebbles, sand, secondary aquatic plants |

During the field studies, water temperature (°C), pH, electrical conductivity (µS/cm) and total dissolved solids (mg/L) contents were measured by using a portable TE-200 meter. In contrast, the flow rate of the water (m/sec.) was measured using a portable YSI Flow Tracker 2 Handheld-type device. Water samples from the surface were transported to the laboratory using 2L dark-coloured glass bottles by cold chain method and analysed without delay. In the laboratory, dissolved oxygen (mg/L by Winkler method), calcium and magnesium (mg/L by EDTA titration), salinity (‰ by Mohr-Knudsen method) and chloride content (mg/L by titration) were measured by titrimetric methods. The macronutrients (phosphate, nitrite nitrogen, nitrate nitrogen and sulphate) were measured and recorded at mg/L values by spectrophotometric methods (Egemen & Sunlu, 1999). In addition, water samples taken from each sampling station during wet and dry seasons were placed in 50 ml polythene bottles, brought to the laboratory by cold chain, acidified by adding 150 µl (1+1) $HNO_3$, and preserved. For elemental analyses, Agilent Technologies 7700 model inductively coupled plasma mass spectrometry (ICP-MS) device was used in TÜTAGEM (Trakya University Technology Research and Development Centre) laboratories according to U.S. Environmental Protection Agency (EPA) 200.7 and 200.8 methods and Aluminum (Al), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Selenium (Se), Strontium (Sr), Cadmium (Cd), Antimony (Sb), Barium (Ba), Thallium (Tl), Lead (Pb), Lithium (Li), Boron (B), Sodium (Na), Potassium (K) contents were measured as ppb. In addition, a total of 181 pesticides were analysed in water samples using liquid chromatography-mass/mass spectrometry (LC-MS/MS) (Agilent 1260 infinity liquid chromatography, Agilent 6460 Triple Quadrupole MS/MS System, Jet Stream Electrospray ion source) (Table 2). For pesticide analyses in the water samples, the QUECHERS method developed for multiple pesticide residue determination in the extraction of pesticides in the sample was applied. In the chromatographic conditions applied, mobile phase gradient programme 0-1 min / A phase 95%, 7-10 min / A phase 5%, 10.10-12 min / 0% A phase, 12.10-13 min / 95% A phase was used (Mobile Phase A; UPW, 5mM Ammonium Formate, 0.1% Formic acid, Mobile Phase B; Acetonitrile, 0. 1% Formic acid, Column; Poroshell 120 EC-C18, 3.0X50mm (2.7 Micron), Flow rate; 0.5 mL/min, Injection volume; 5 µL, Column Temperature; 40°C, Ionisation Mode; ESI(+), Mode; Dynamic MRM, Gas temperature and flow; 325°C and 10 L/min, Nebulizer; 40 psi, Capillary; 3 kV). The chromatographic operating conditions for pesticide analysis are given in Table 3.

Sediment samples were taken from the sampling stations using a simple mud-grab, and benthic macroinvertebrate samples were collected by sifting the sediment through sieves. Sediment samples were taken from the sampling stations using a simple mud-grab, and benthic macroinvertebrate samples were collected by sifting the sediment through sieves. Benthic macroinvertebrates were also collected from submerged parts of aquatic plants and under stones in water. The obtained materials were put into polyethene bottles, which included 70% ethanol. Benthic macroinvertebrates were sorted under a stereo binocular microscope in the laboratory. Timm (1999), Wetzel et al. (2000), and Karaman and Pinkster (1977) were consulted to determine the taxonomical identification of the groups.

**Table 2.** List of pesticides measured at the water samples

| | | | | |
|---|---|---|---|---|
| Acephate | Cycluron | Fluometuron | Mevinphos | Siduron |
| Acetamiprid | Cymoxanil | Fluoxastrobin-698 | Mexacarbate | Simetryn |
| Acibenzolar-S-Methyl | Cymoxanil | Fluquinconazole -699 | Monocrotophos | Spinetoram-741 |
| Aldicarb | Cyprodinil | Flusilazole | Monolinuron | Spinosad A |
| Aldicarb sulfone | Cyromazine | Flutolanil-703 | Myclobutanil | Spirodiclofen |
| Aldicarb sulfoxide | Desmedipham | Flutriafol | Neburon | Spiromesifen |
| Ametryne | Dicrotophos | Forchlorfenuron-706 | Novaluron | Spirotetramat |
| Aminocarb | Diethofencarb | Formetanate-hydrochloride | Nuarimol | Spiroxamine |
| Amitraz | Difenoconazol | Fuberidazole-707 | Omethoate | Tebuconazole |
| Azoxystrobin | Diflubenzuron | Furalaxyl | Oxadixyl | Tebufenozide |
| Benalaxyl-M | Dimethoate | Furathiocarb | Oxamyl | Tebufenpyrad |
| Bendiocarb | Dimoxystrobin-688 | Hexaconazole | Paclobutrazol | Tebuthiuron |
| Benfurocarb | Diniconazole | Hexaflumuron | Penconazole | Teflubenzuron |
| Benzoximate | Dinotefuran | Hexythiazox | Pencycuron | Terbumeton |
| Bifenazate | Diuron | Hydramethylnon | Phenmedipham | Terbutryn |
| Bitertanol | Emamectin-Benzoate | Imazalil | Picoxystrobin | Tetraconazole |
| Boscalid | Epoxiconazole | Indoxacarb | Piperonyl butoxide | Thiabendazole |
| Bromuconazole | Etaconazole | Ipconazole-713 | Pirimicarb | Thiacloprid |
| Bupirimate | Ethiofencarb | Iprovalicarb | Prochloraz | Thiamethoxam |
| Buprofezin | Ethirimol | Isoprocarb | Promecarb | Thidiazuron-747 |
| Butocarboxim | Ethofumasate | Isoproturon | Prometon | Thiobencarb-748 |
| Butoxycarboxim | Etoxazole | Kresoxim-methyl | Prometryn | Thiofanox |
| Carbaryl | Famoxadone | Linuron | Propamocarb-hydrochloride | Thiophonate Methyl |
| Carbendazim | Fenamidone | Lufenuron | Propargite | Triadimefon |
| Carbetamide | Fenarimol | Mandopropamid | Propham | Triadimenol |
| Carbofuran | Fenazaquin | Mefenacet | Propiconazole | Trichlorfon |
| Carbofuran-3-hydroxy | Fenbuconazole | Mepronil | Propoxur | Tricyclazole-753 |
| Carboxin | Fenhexamid | Mesotrione | Prothioconazole -734 | Trifloxystrobin |
| Carfentrazone Ethyl | Fenobucarb | Metalaxyl | Pymetrozine | Triflumizole |
| Chlorantraniliprole | Fenproprimorph | Metconazole -718 | pyracarbolid | Triflumuron |
| Chlorfluazuron | Fenuron | Methabenzthiazuron-719 | Pyraclostrobin | Triticonazole |
| Chlorotoluron | Fibronil | Methamidophos | Pyridaben | Vamidathion |
| Chloroxuron | Fluazinam | Methiocarb | Pyrimethanil | Zoxamide |
| Clethodim -682 | Flubendiamide -695 | Methoprotryne | Pyriproxyfen | |
| Clofentezine | Fludioxonil | Methoxifenozide | Quinoxyfen | |
| Clothianidin | Flufenacet | Metobromuron | Rotenone-739 | |
| Cyazofamid | Flufenoxuron | Metribuzin | Secbumeton | |

**Table 3.** Chromatographic examination conditions used in pesticide analyses

| | | | |
|---|---|---|---|
| Mobile Phase | | A: UPW, 5mM Ammonium Formate, 0.1% Formic Acid<br>B: Acetonitrile, 0.1% Formic Acid | |
| Column | | Poroshell 120 EC-C18, 3.0x50mm, 2.7 Micron | |
| Flow speed | | 0,5 mL/minute | |
| Injection volume | | 5 µL | |
| Column Temperature | | 40°C | |
| Ionisation Mode | | ESI(+) | |
| Gas temperature and flow | | 325°C and 10 L/minute | |
| Nebulizer | | 40 psi | |
| Capillary | | 3 kV | |
| Timing | Time (min) | A (%) | B (%) |
| | 0.00 | 95.0 | 5.0 |
| | 1.00 | 95.0 | 5.0 |
| | 7.00 | 5.0 | 95.0 |
| | 10.00 | 5.0 | 95.0 |
| | 10.10 | 0.0 | 100.0 |
| | 12.00 | 0.0 | 100.0 |
| | 12.10 | 95.0 | 5.0 |

## Results and Discussion

Table 4 provides data on some environmental parameters measured during the wet and dry seasons at 3 stations selected from Sızır Waterfall. The data show that the flow rate, which varied between 0.66-1.1 m/sec in the wet season, decreased to 0.1-0.45 m/sec in the dry season, and this decrease was quite evident at station 3 (St.3).

It was determined that the water temperature, an average of 25 ˚C in the wet season, increased to 30 ˚C in the dry season. The water hardness measured at the sampling stations varied between 22-34 ˚FS and showed hard water characteristics, possibly due to the high Ca ion values measured. Sızır Waterfall exhibits a completely freshwater characteristic according to the measured salinity values and does not exceed the expected value in freshwater resources in measured conductivity values. However, at St.3, this value increases during the dry season (1966 µS/cm).

The other measured environmental variables were compared with the values in the Water Pollution Control Regulation of Türkiye (SKKY, 2008). According to this, it was found that the measured TDS (total dissolved matter) values decreased to Class II Water Quality level at St.3 during the dry season; the pH values range from 7.5 to 8.2 and indicate Class I Water Quality level; the dissolved oxygen value remained low (signs Class III Water Quality Level), with a maximum of 5.71 mg/L (in the wet season at St.2) and a minimum of 2.85 mg/L (in the dry season at St.3); chloride ions was found as Class I Water Quality level; the macronutrient salt (phosphate, nitrite nitrogen, nitrate nitrogen) values were found to exceed the Class I Water quality values, except for the sulphate value (in Class I Water Quality in terms of sulphate).

The relationship between physicochemical parameters was evaluated by applying the Pearson Correlation Analysis (Krebs, 1999). Accordingly, a positive correlation was found between $NO_2$-N and $PO_4$; $NO_3$-N and pH; Cl and EC; Cl and TDS; EC and TDS. Correlation coefficients are given in Table 5.

The data on measured elements are presented in Table 6. The obtained values were compared with the water quality classes in the Surface Water Resources Control Regulation of Türkiye (YSKKY, 2016). According to this, it was determined that B, Al, As, Cu, Ba, Ba, Zn, Fe, Cd, Co, Cr, Pb, Ni and Se values did not exceed the Class I water quality level, but Mn value exceeded (<100 µg/L) only in the dry season at St.2. V and Sb values were found below the Maximum Permissible Environmental Quality Standard values (MAK-ÇKS) given in YSKKY (2016), and the measured Li ratio was found below the values found in the lakes of Türkiye (Helvacı, 2018). Na ratio, which is stated to be a maximum of 100 mg/L in natural inland waters, and K ratio, which is stated to be a maximum of 10 mg/L in natural waters, were not found to exceed these values in this study (Boyd, 1998; Tepe et al., 2006).

Sampling locations were also compared for physicochemical and elemental contents by Bray-Curtis Cluster Analysis (Fig 2). Accordingly, while there was no significant difference between the sampling stations in terms of both physicochemical and element contents in the wet season, St.3 exhibited different characteristics from the other stations in the dry season (similarity < 50%). Especially the fact that the B, Na, Al, K, V, Co, Ni, Cu, Sr, Cd and Ba values measured in the dry season at station number 3 are higher than the other stations significantly reduces the similarity rate (similarity < 20%) (Fig 3). Although a total of 181 types of pesticides were analysed, no pesticides were found.

Benthic macroinvertebrates collected from the sampling stations were identified taxonomically. In the identification of taxa, the smallest possible taxonomic category was used. *Potamothrix* sp. from Oligochaeta, *Physa* sp. from Gastropoda, *Gammarus pseudosyriacus* from Amphipoda, *Baetis* sp. nymphs from Ephemeroptera, and nymphs and larvae from Plecoptera, Trichoptera, Coleoptera, Diptera and Odonata were found (Table 7).

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**Table 4.** Data on some environmental variables in Sızır Waterfall

| | | St. 1 | St. 2 | St. 3 |
|---|---|---|---|---|
| **Wet Season** | Velocity (m/sec) | 0.66 | 0.8 | 1.1 |
| | Water Temperature (°C) | 26 | 25 | 24 |
| | pH | 7.59 | 7.91 | 7.85 |
| | Conductivity (µS/cm) | 451 | 440 | 635 |
| | Dissolved Oxygen (mg/L) | 4.95 | 5.71 | 5.52 |
| | Total Hardness (°FS) | 22.4 | 33.4 | 22 |
| | Ca (mg/L) | 89.77 | 92.9 | 88.17 |
| | Mg (mg/L) | 2.72 | 5.30 | 16.09 |
| | Chloride (mg/L) | 2.99 | 3.99 | 4.99 |
| | Salinity (‰) | 0.01 | 0.02 | 0.01 |
| | TDS (ppm) | 225 | 187 | 220 |
| | $PO_4$ (mg/L) | 0.220 | 0.91 | 0.234 |
| | $SO_4$ (mg/L) | 0.417 | 0.277 | 1.988 |
| | $NO_3$-N (mg/L) | 21.79 | 33.18 | 33.62 |
| | $NO_2$-N (mg/L) | 0.019 | 0.19 | 0.019 |
| | | **St. 1** | **St. 2** | **St. 3** |
| **Dry Season** | Velocity (m/sec) | 0.32 | 0.45 | 0.12 |
| | Water Temperature (°C) | 29 | 31 | 30 |
| | pH | 7.82 | 7.95 | 8.23 |
| | Conductivity (µS/cm) | 547 | 530 | 1966 |
| | Dissolved Oxygen (mg/L) | 4.76 | 3.80 | 2.85 |
| | Total Hardness (°FS) | 31 | 25 | 34 |
| | Ca (mg/L) | 9.37 | 33.66 | 104.28 |
| | Mg (mg/L) | 4.69 | 5.05 | 5.10 |
| | Chloride (mg/L) | 1.99 | 0.99 | 26.99 |
| | Salinity (‰) | 0.02 | 0.01 | 0.01 |
| | TDS (ppm) | 273 | 265 | 1013 |
| | $PO_4$ (mg/L) | 0.386 | 0.261 | 0.400 |
| | $SO_4$ (mg/L) | 0.922 | 0.660 | 2.592 |
| | $NO_3$-N (mg/L) | 33.85 | 43.70 | 55.53 |
| | $NO_2$-N (mg/L) | 0.047 | 0.041 | 0.028 |

**Table 5.** Pearson correlation analysis

| | $NO_2$-N | $NO_3$-N | pH | $PO_4$ | Cl | EC | TDS |
|---|---|---|---|---|---|---|---|
| $NO_2$-N | 1 | | | | | | |
| $NO_3$-N | -,110 | 1 | | | | | |
| pH | ,080 | ,970** | 1 | | | | |
| $PO_4$ | ,969** | ,031 | ,234 | 1 | | | |
| Cl | -,185 | ,750 | ,778 | ,033 | 1 | | |
| EC | -,282 | ,818* | ,813* | -,067 | ,986** | 1 | |
| TDS | -,276 | ,816* | ,798 | -,063 | ,974** | ,992** | 1 |

*: correlation significant at 0.05 level ($p < 0.05$);

****: correlation is significant at 0.01 level ($p < 0.01$);**

-: No statistically significant correlation was detected

**Table 6.** Data on some elements in Sızır Waterfall (ppb)

| | Wet Season | | | | Dry Season | | |
|---|---|---|---|---|---|---|---|
| | St. 1 | St. 2 | St. 3 | | St. 1 | St. 2 | St. 3 |
| Li | 1.84 | 1.65 | 1.18 | | 1.08 | 0.66 | 1.37 |
| B | 4.80 | 3.90 | 3.80 | | 2.70 | 1.60 | 14.11 |
| Na | 505.42 | 607.45 | 853.64 | | 401.93 | 383.00 | 24206.83 |
| Al | 3.76 | 7.93 | 12.59 | | 4.24 | 6.49 | 24.08 |
| K | 395.66 | 625.14 | 439.35 | | 360.67 | 452.75 | 1317.89 |
| V | 1.80 | 1.92 | 2.16 | | 1.51 | 1.65 | 3.18 |
| Cr | 3.11 | 3.91 | 20.91 | | 2.12 | 2.21 | 4.80 |
| Mn | 0.48 | 0.84 | 4.87 | | 19.49 | 136.96 | 44.50 |
| Fe | 32.49 | 41.51 | 88.69 | | 28.38 | 36.11 | 92.67 |
| Co | 0.21 | 0.17 | 0.20 | | 0.13 | 0.12 | 0.32 |
| Ni | 1.08 | 1.17 | 1.26 | | 1.56 | 1.01 | 4.17 |
| Cu | 5.16 | 4.74 | 5.90 | | 3.12 | 3.02 | 8.50 |
| Zn | 30.89 | 15.11 | 14.54 | | 8.93 | 8.06 | 13.03 |
| As | 3.10 | 6.04 | 43.48 | | 4.92 | 9.11 | 12.13 |
| Se | 0.73 | 0.79 | 1.10 | | 1.71 | 1.22 | 1.22 |
| Sr | 252.49 | 267.91 | 294.41 | | 286.65 | 255.05 | 2449.07 |
| Cd | 0.04 | 0.03 | 0.02 | | 0.03 | 0.02 | 0.05 |
| Sb | 0.40 | 0.38 | 0.28 | | 0.26 | 0.23 | 0.38 |
| Ba | 20.67 | 31.89 | 33.56 | | 98.03 | 120.92 | 204.24 |
| Tl | 0.010 | 0.005 | 0.005 | | 0.005 | 0.004 | 0.005 |
| Pb | 1.24 | 1.30 | 1.87 | | 4.65 | 4.51 | 4.66 |

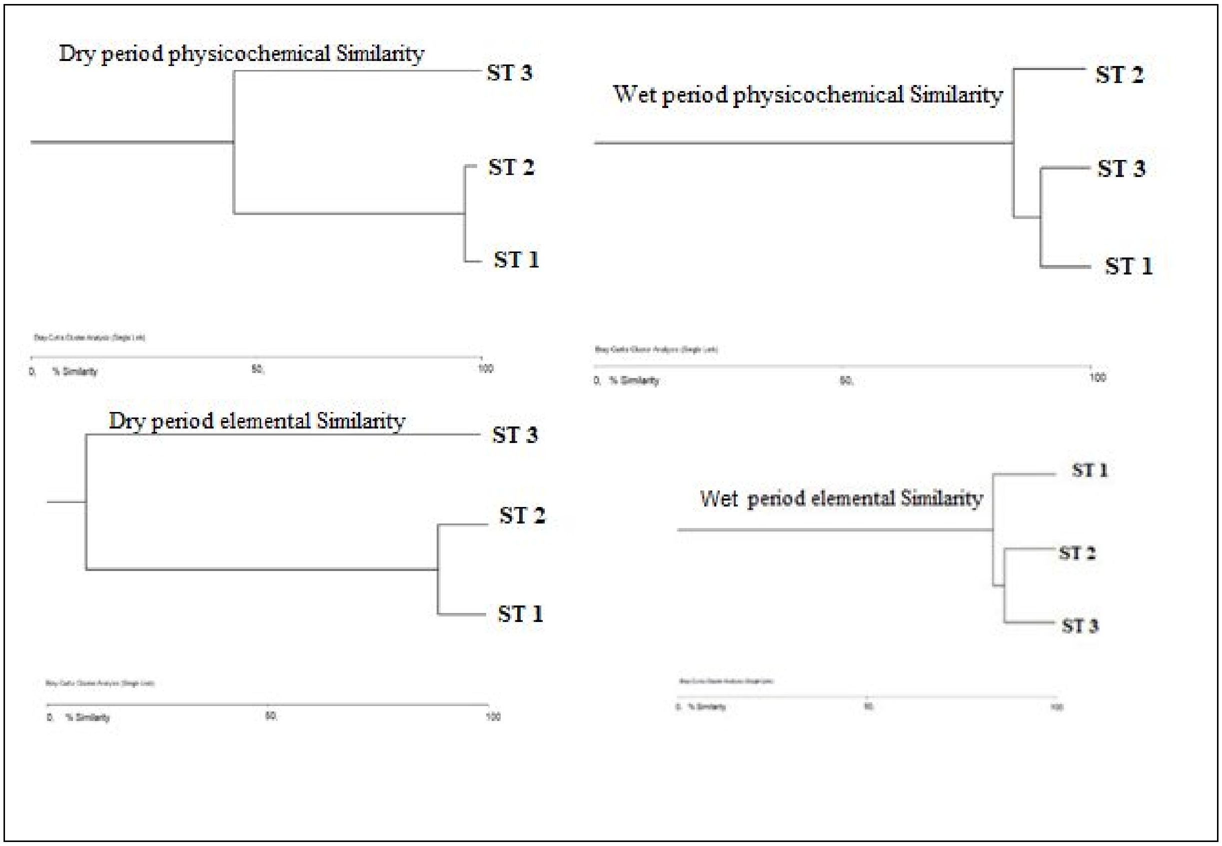


**Figure 2.** Bray-Curtis cluster analysis results for the physicochemical and elemental contents of the sampling stations

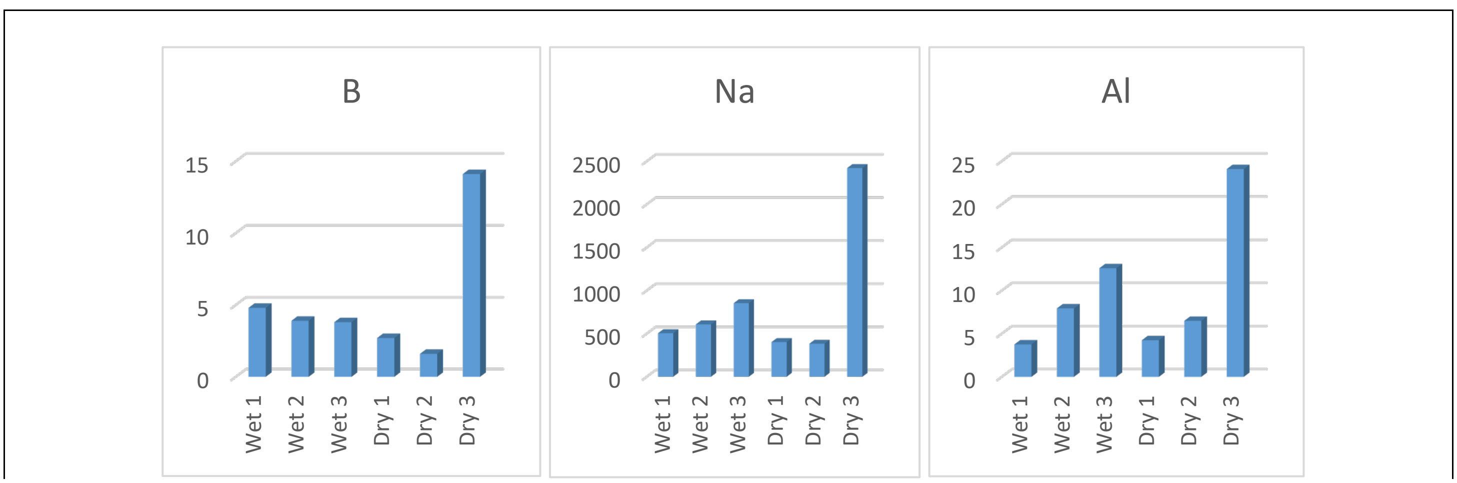


**Figure 3.** Comparison of data on some elements measured at sampling stations (1,2,3: station numbers)

**Table 7.** Benthic macroinvertebrates determined in the sampled stations of Sızır Waterfall

| | Taxa | St. 1 | St. 2 | St. 3 |
|---|---|---|---|---|
| **Wet Season** | Oligochaeta | - | - | *Potamothrix* sp. |
| | Amphipoda | *G.pseudosyriacus* | *G.pseudosyriacus* | - |
| | Ephemeroptera | - | *Baetis* sp. | *Baetis* sp. |
| | Trichoptera | - | larvae | - |
| | Coleoptera | - | larvae | - |
| | | | | |
| **Dry Season** | Oligochaeta | *Potamothrix* sp. | - | - |
| | Gastropoda | *Physa* sp. | - | *Physa* sp. |
| | Amphipoda | *G. pseudosyriacus* | - | - |
| | Ephemeroptera | - | *Baetis* sp. | - |
| | Plecoptera | - | - | nymph |
| | Odonata | - | - | Zygoptera nymph |
| | Diptera | - | - | Chaoboridae larvae |

At St. 1, *G. pseudosyriacus* was determined during the wet season and *Potamothrix* sp., *Physa* sp., and *G. pseudosyriacus* during the dry season. At the St. 2, *G. pseudosyriacus*, *Baetis* sp., Trichoptera and Coleoptera larvae were determined in the wet season and *Baetis* sp. in the dry season. At St. 3, *Potamothrix* sp. and *Baetis* sp. were found in the wet season; *Physa* sp., Plecoptera nymph, Zygoptera nymph and Chaoboridae larvae were found in the dry season.

Hussen et al. (2018) used water samples taken from three locations: upstream, waterfall, and downstream during the rainy season to analyse the physical and chemical parameters (pH, conductivity, turbidity, water and air temperatures, velocity, Biochemical oxygen demand, Dissolved oxygen, nitrate, orthophosphate, COD, and phosphate) of a waterfall in Indonesia. They reported that the water from the waterfall does not comply with drinking water standards but is suitable for tourism, fishing and irrigation. This study chose three locations (upstream, waterfall and downstream) to analyse the environmental variables in Sızır Waterfall during the wet and dry seasons. The high hardness values in Sızır Waterfall, in particular, affect the water's drinkable quality negatively. Sızır Waterfall waters are more suitable for agricultural irrigation due to their high nutritional salt content.

When some physicochemical findings obtained from the previous studies conducted in waterfalls in Türkiye are examined, Çağlar & Saler (2014) recorded that the water temperature ranges between 12.0-24.4 ºC, pH values as 8.0-8.8, dissolved oxygen as 8.1-9.6 mg/L, chloride value as 0.90-1.11 mg/L in Koçan Waterfall where the water was classified as "medium hard" in terms of total hardness. Saplıoğlu et al. (2017) evaluated the water quality data of Karpuz Stream, Düden Stream and Kurşunlu Waterfall and they reported that pH values as 7.4-7.8, sulphate value as 20.8-58.9 mg/L and hardness as 5.3-9.97 °FS. In this study, pH values in Sızır Waterfall varied between 7.5 and 8.2; oxygen value was between 2.85-5.71 mg/L, chloride value was between 0.99 mg/L (St.2, waterfall station) and 26.99 mg/L (St.3, downstream), sulphate value was between 0.2-2.5 mg/L and water hardness was between 22-34 °FS.

In a previous study performed by Aydın & Ekmekçi (2005), the pH value was reported as 7.3 on average in the physicochemical measurements of the location specified as the Sızır source. The pH values were determined in our study's range of 7.5-8.2. Conductivity values measured between 440 and 635 µS/cm in our study were in parallel with the average value of 796 µS/cm determined by Aydın & Ekmekçi (2005). However, it was observed that it exceeded these values (1966 µS/cm) at St. 3 during the dry season.

Nyamangara et al. (2008) investigated the effects of sewage and industrial wastewater on Harare Falls and the lower Mukuvisi River (Zimbabwe). They determined the concentrations of Zn, Cu, Pb, and Cd in water and sediment samples and reported that the upstream sampling sites contained the highest concentrations of all metals compared to the other locations. Zn and Cd values determined in our study were compared to the findings of Nyamangara et al. (2008) and were found to be similar.

Sharifah Aisyah et al. (2015) recorded the presence of sensitive organisms such as Ephemeroptera, Plecoptera and Trichoptera in a waterfall in Malaysia. They reported that benthic macroinvertebrate communities were more abundant downstream than upstream. In our study, specimens belonging to these three sensitive groups were found. It was also observed that the benthic macroinvertebrate findings were similar to their findings (3 taxa upstream, four taxa at the waterfall, and six taxa downstream).

In a study performed by Baker et al. (2017) on benthic sampling from the upper and lower parts of a waterfall in Brunei and another study performed by Andrade et al. (2020) on EPT (Ephemeroptera, Plecoptera, Trichoptera) diversity in the upper and lower parts of a waterfall in Brazil, close similarities between the lower and upper parts of rivers were reported. In a study performed by Demir (2020) including some waterfalls in Türkiye, Ephemeroptera (in Manavgat Waterfall) and Trichoptera (in Ilıca Waterfall) individuals were found with the highest and lowest rates, respectively. Zakiah et al. (2022) reported that in the study performed in different waterfalls in Malaysia, individuals belonging to Ephemeroptera were found at the highest rate in the upstream and individuals belonging to Trichoptera in the downstream.

Mello and Abessa (2021) evaluated a waterfall's physical-chemical parameters and macrobenthic organisms in Brazil. They observed a higher density of Diptera than other groups due to their wide tolerance range. Clayton and Pearson (2016) reported, in a study performed in 5 different waterfalls in Australia, that the highest number of samples were found to belong to the Diptera group. However, the waterfalls differed significantly regarding general invertebrate abundance and diversity. Our study found Diptera samples only at St. 3 (downstream) in Sızır Waterfall. This station had high values, especially regarding conductivity, chloride and sulphate. *G. pseudosyriacus* reported from freshwater sources with conductivities of 120-1015 µS/cm (Zamanpoore et al., 2011) was observed at St.1 (upstream) and St.2 (waterfall) in our study. The high conductivity value (1966 µS/cm) measured at St.3 (downstream) may be an environmental factor limiting the presence of this species.

Rackemann et al. (2013) studied taxonomic diversity in 12 waterfalls in Australia. They selected three stations from each waterfall and sampled the autumn and winter seasons. They reported that taxonomical diversity increased in waterfalls covered with density moss; these ecosystems were used as shelters for rheophilic species, especially during low-flow seasons. Our study observed the highest diversity in St.3, which has the lowest flow velocity.

## Conclusion

To ensure the sustainable use of aquatic ecosystems, these environments' physical, chemical and biological components must interact in a balanced manner. The healthy ecological structure of special ecosystems such as waterfalls also depends on these three important components. However, with the entry of some pollutants into the ecosystem, the environmental components in the water change, thus disrupting the balance in the aquatic environment and causing damage to biodiversity.

In conclusion, waterfalls are important aquatic ecosystems with unique characteristics. Therefore, it is recommended that studies on waterfalls be evaluated from a biological point of view and that physical and chemical properties be determined.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declare no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** This study does not require ethics committee permission or any special permission.

**Data availability:** Data will be made available on request.

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