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Research Article

Struma River-Water, Environment, Biodiversity, and Agriculture

Anton Sotirov

Institute of Agriculture-Kyustendil, Agricultural Academy, Bulgaria, Department of Agrotechnology, Plant Protection and Economics, 2500, Kyustendil, Str. Sofiisko Shose, Bulgaria
Email: a_sotir@iz-kyustendil.org

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Abstract
General aim of the study is to be presented summarized data, result of 15 years investigations of the valley of Struma River, which springs from the Vitosha Mountain near the capital city of Sofia, Bulgaria and flows into Mediterranean Sea in Greece near the city of Thessaloniki. The study has begun during 2007–year of the acceptance of Bulgaria in EU and it has continued by now during 2023. Bulgaria, Serbia, North Macedonia, and Greece) are the illegal landfills, dumping of waste and household waste water canals, result of the living process of the local population without respect to any National and EU legislation. Equal to this harm is the poor work of municipal and governmental authorities towards waste management of the area. Second source of contamination is farming and construction activities. Usage of fertilizers is widespread in the area during spring and summer period. Farming and construction waste dumped illegally in river beds also contaminates the water and soils in the area. The region is not industrially developed and industry is not the main pollutant of the area. It is established that population of the fish species closely relates to contamination of the water. Contaminated rivers do not have any fish species. Feeding streams bring contamination into Struma River and decrease population of some fish species such as brown trout fish (*Salmo trutta fario).* This specie disappears in water, contaminated with cyanuric acid (Novoselska and Bistritsa Rivers) or in water contaminated with thermal mineral water (Banshtitsa River).
Keywords: Water, Rivers, Struma, Contamination, Agriculture, Environment.

1. Introduction

Town of Kyustendil is situated in South-West Bulgaria, near mountain Osogovo (Figure 1). It is located in the central part of the Balkan Peninsula (South Europe) with altitude of 512 m. The climate of the town is transitional continental to Mediterranean. Rainfalls are not very intensive with an annual rate of about 589 mm. They are almost equally distributed over the seasons. Snow falls from November to March and the average thickness of snow is 30 cm with duration of about 15 days. However, the area has many water sources: rivers, springs, lakes, mineral and ground water (Ivanchev, 1996).

Figure 1. Location of the studied area (*Areas of sampling and measurements).

The biggest river in the area is the Struma River. The Struma River springs from 2246 m above sea level, closely to the peak Cherni Vrah (2290 m) of the Vitosha Mountain, Bulgaria. The length of the river is 415 km from which 290 km are situated in Bulgaria and the rest 125 km are situated in Greece, where the river flows into the Mediterranean Sea (Figure 1). By this way Struma River might appear as a cross-border pollutant for more than two countries. The river has seven big right-side feeders, which are objects of the study: Treklyanska River, Dragovishtitsa River, Bistritsa River, Novoselska River, Banshtitsa River, Eleshnitsa River, and Strumeshnitsa River. Dragovistitsa River is a cross-border river and it flows through Serbia and Bulgaria. Strumeshnitsa River is also a cross-border river and it flows through North Macedonia and Bulgaria. Studied Struma River flows through Bulgaria and Greece and it inflows into the Aegean Sea. Treklyanska River is 54 km long. Dragovishtitsa River, which length is 70 km is a right tributary to the Struma River and flows through Southeastern Serbia (45 km) and Western Bulgaria (25 km). Bistritsa River has 51 km length. Banshtitsa River is 22 km long, Novoselska River is 25 km long and Eleshnitsa River is 59 km long. All five feeders spring at the cross-border area between Bulgaria and neighbor countries Serbia and North Macedonia. Along the length of the Struma River is the Strumeshnica River which springs from North Macedonia and inflows in the Struma River in Western Bulgaria. Strumeshnica River is 114 km long from which 81km are in North Macedonia and 33 km are in Bulgaria. Information about the topic is published only by our research team (Sotirov *et al.,* 2013; 2014; 2015; 2016).

The most widespread fish species in all 8 of the studied rivers are: *Leuciscus cephalus, Barbus,* but most important as an environmental bio-indicator is *Salmo trutta fario* (brown trout)*.* This species is under special fishing regime by the Bulgarian government. It is sensitive to some parameters of the environment such as dissolved oxygen, temperature and most important it is sensitive to presence of cyanuric acid in the water. Cyanuric acid is a product of decomposition of domestic waste in the illegal landfills along the rivers, which are the main source of contamination observed in the studied area. It is considered that this fish species disappears when the concentration of the cyanuric acid becomes more than 8 mg/l. Other bio-indicator for this parameter is the fresh water shrimp *Branchiopoda,* which we also studied. The whole territory is a part of the European Green Belt. Total 37,248 hectares from the territory of municipality Kyustendil is included in the protected area NATURE 2000. The following bird species are protected (Sotirov *et al.,* 2011): *Pernis apivorus, Alectoris graeca, Emberiza hortulana, Dendrocopos syriacus, Falco peregrinus, Aquila chrysaetos*, *Lanius collurio, Crex.* Following plant species are protected in the area: *Fritillaria pontica, Red paeonia, Astragalus spruneri, Iris reichenbachii, Orchid.* Main bio-indicator of the study Fish *Salmo trutta fario* (brown trout) is under protection and under special fishing and breeding regime.

Environmental monitoring is the process of observation of the environment for all components (air, water, soil, rocks, ecosystems, species, crops, biodiversity, etc.) and warning about probable emergencies, hazardous or dangerous to the environment and people (Parkin *et al.,* 2003). A network of stations is created to collect data about the state of the environment throughout the country. The location of the stations is established on a scientific basis. There is a rule the stations to be build around pollutants. Measurement must be done for all components of the environment: air, surface and groundwater, soil and rocks, species, and waste moving. Environmental monitoring gives an idea for the current state of the studied system or object, but if there is data from previous monitoring, reliable information about the trends of the observed system can be obtained. Well-organized monitoring provides a set of data that is necessary for statistical modeling of the object or system (Simeonova and Lovchinov, 2008).

2. Materials and Methods

General aim of the study is to be presented summarized data, result of 15 years investigations of the Valley of Struma River, which springs from the Vitosha Mountain near the capital city of Sofia, Bulgaria and flows into Mediterranean Sea in Greece near the city of Thessaloniki. The study has begun during 2007–year of the acceptance of Bulgaria in EU and it has continued by now during 2023. This is a part of continuous environmental monitoring, needed for achieving of sustainable development of the region and preservation of the natural resources for future generations, including water, soil, air, forests, biodiversity, fishery, and agricultural lands. Specific aim of the project is to obtain information about the quality and possible contamination of the water and sediments along the cross-border Struma River and some of its feeders and the influence of the water contamination on the distribution of the river fish species. Study is necessary, because the biggest river in the area and its 7 flows cross large cross-border area between 4 European countries. Area has about 100% agricultural and fishing mean for the livelihood. Water of the studied rivers is used mainly for irrigation, farming, drink water, tourism, fishing, and food industry. The study is performed along Struma River at its most important inflows and at the places of the confluence of her feeders: Treklyanska River, Dragovishtitsa River, Banshtitsa River, Bistritsa River, Novoselska River, Eleshnitsa River, and Strumeshnitsa River. The research is done in order to gather perennial data about the condition of the Struma River and its inflows and to prepare a database for comparison for future studies and taken of decisions and measures. The data will be used to obtain valuable information about the agricultural and fishing value of the river at the time of the study. Data was included in the National System for Bio-monitoring of the Ministry of Environment and Water of Republic of Bulgaria.

Methods are selected in accordance to the Bulgarian National System for monitoring the environment which supports database at national and regional level. National System for Environmental Monitoring performs constant reviews in many static and mobile stations. It is coordinated with the EU environmental regulations. The present study includes measurements of basic physical and chemical parameters of the water of Treklyanska River, Dragovishtitsa River, Novoselska River, Banshtitsa River, Bistritsa River, Eleshnitsa River, Strumeshnitsa River, and the Struma River. Samples were taken and measurements were made at intervals of about 500 meters along the inflowing rivers and at the point of their confluence into the Struma River (Figure 1). Struma River was measured before and after each studied inflow and at most important points such as exit from Bulgaria and entrance of the river in Greece and at the place of inflow of the river into the Aegean Sea in Greece.

Investigation of fish passages was done using radar (sonar) for fish passages. Fish species are determined by method of interview of the fishermen, fish specialists and direct observation. Radiation of the water and the common radiation background were measured with a Geiger counter "Radex" RD1503. Measurements were performed with an instrument "SensoDirect 150", which measures the acidity of the water (pH), water temperature (t, °C), electrical conductivity (EC, μS), total dissolved solids (TDS, ppm), dissolved oxygen(O_2, %). Measurements were performed also with an instrument "Hanna" HI 9813-6, which measures the acidity of the water (pH), water temperature (t, °C), electrical conductivity (EC, μS), total dissolved solids (TDS, ppm). Other devices used for testing the water in the river are spectrophotometers (colorimeters) "Lovibond" and “Lovibond MD 600”. With the help of theese nstruments the following parameters are identified: free, total and combined chlorine Cl, acidity pH, cyanuric acid, total alkalinity, free, total and combined copper and free iron. We used also binocular (stereo) microscope USB “CETI” (STAR-24ED) with a computer program “Globecam-D” and digital microscope USB 2.0 DigiScope and Digital Microscope with a computer program MAC with white and fluorescent (blue) light in order to study the micro-detritus in the sediment of the river. Nitrate and nitrite content in the water are measured by using test strips with a range of 0-10-25-50-100-250-500 mg/l. Arsenic content in the water is measured by the usage of test strips with a range of 0.005-0.0010-0.0025-0.05-0.1-0.25-0.5 mg/l. Zinc content in the water is measured by the usage of test strips with a range of 0-4-10-20-50 mg/l. Lead content in the water is measured by the usage of test strips with a range of 20-40-100-200-500 mg/l. Manganese content in the water is measured by the usage of test strips with a range of 2-5-20-50-100 mg/l.

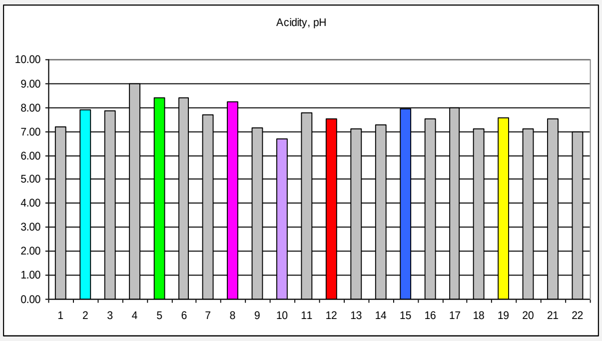
Sulfate and sulfite content in the water are measured by using test strips with a range of 200-400-800-1200-1600 mg/l for SO_4 and 10-40-80-180-400 mg/l for SO_3. The team will continue environmental measurements in the future to determine the seasonal variation of the parameters of the water, as well as taking steps and decisions in case of the event of established dangerous levels of pollution. For bio-monitoring we used portable sonar (radar) for fish passages “Fish Finder” with monochromatic LCD screen, one-ray, frequency 200 kHz, maximum depth 100 m, picture of bottom relief. Also a microbiological survey for coliforms in some of the rivers is performed under Bulgarian State Gazette BDS EN ISO/IEC 17025: 2006.

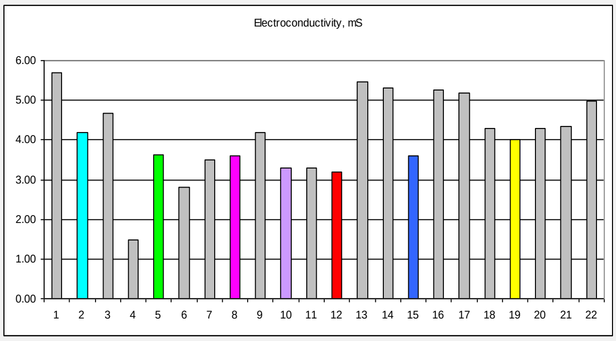
For fruit and vegetable study the instruments were used as follow: Brix refractometer “MA871” for measurement of the total sugar content by Brix (%) and "Waterproof IP57" tester for determination of total acidity (pH), electrical conductivity (μS/sec), total dissolved solids (ppm), total salt content (ppm). Sensory testing was performed also, such as taste, aroma, color and turbidity of the juice and the separated fruit puree. Fruit juice (100%) is obtained by the method of cold pressing with a single-shaft juicer Star Light SJB-150 R, unpasteurized, without additives. The applied method of measurement is "on spot" ("in-situ"), on terrain, throughout direct sampling ("grab samples"), because the advantages of this method are high accuracy and correctness of the research. Digital (electronic) devices are used for the accomplishment of the study because of their ability to quickly, easily and accurately measure the parameters on terrain.

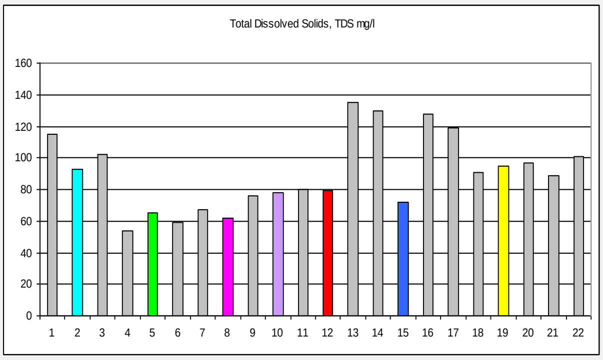
3. Results and Discussion

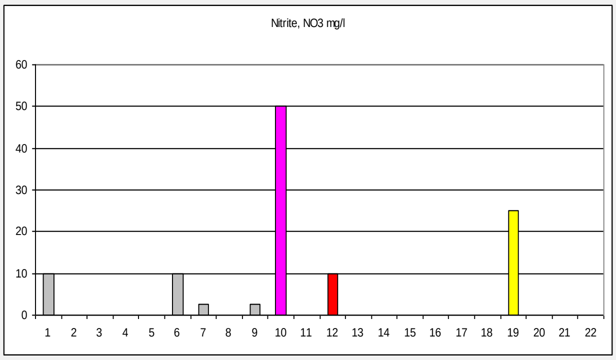
3.1. Results

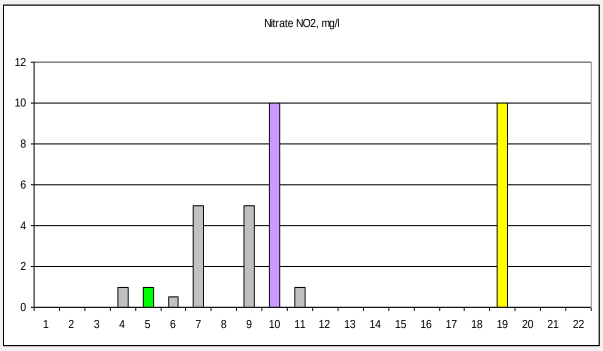
Figure 2 shows the measured parameters of the water of Struma River in grey color and its feeding streams with different colors.

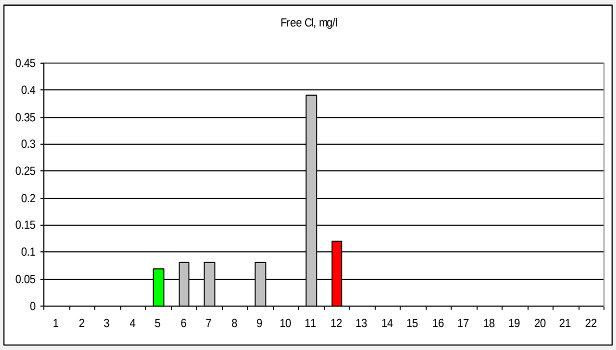

Acidity, pH
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

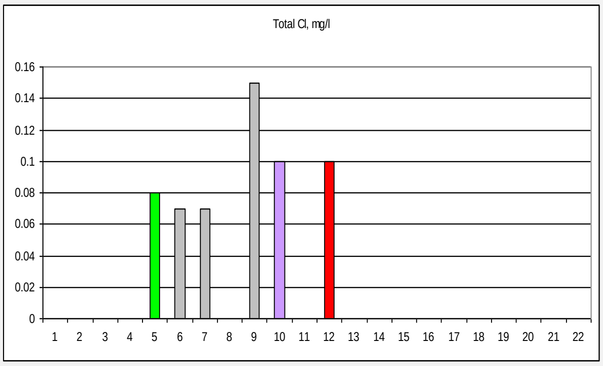

Electroconductivity, mS
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

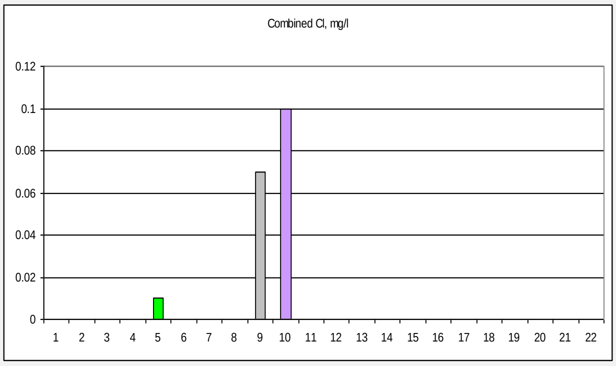

Total Dissolved Solids, TDS mg/l
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

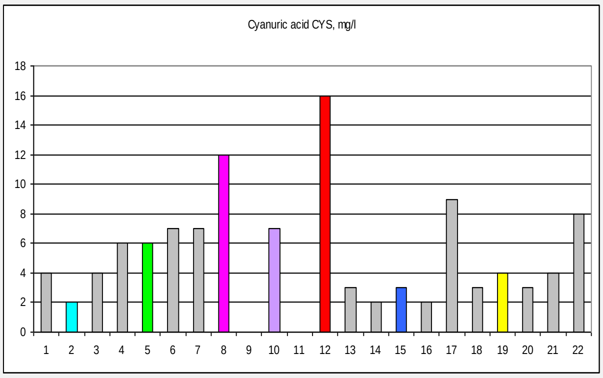

Nitrite, NO3 mg/l
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

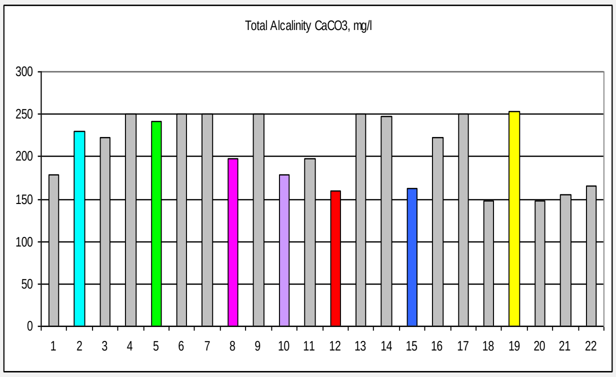

Nitrate NO2, mg/l
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

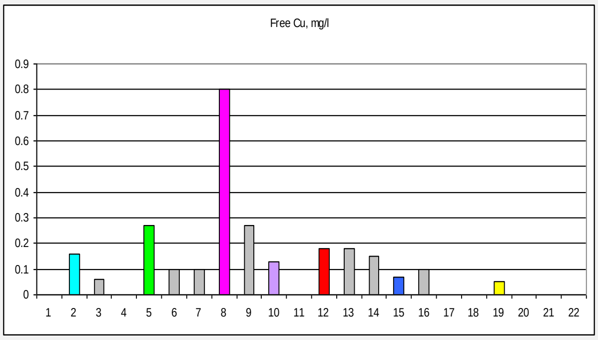

Free Cl, mg/l
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

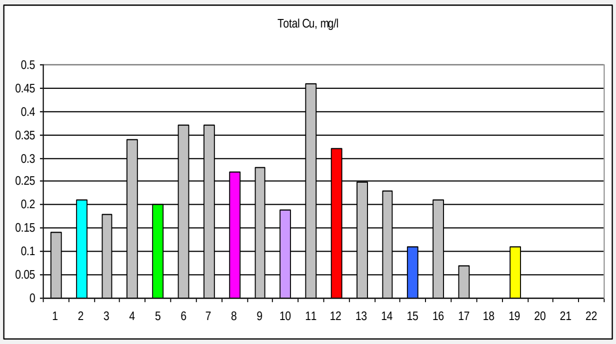

Total Cl, mg/l
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

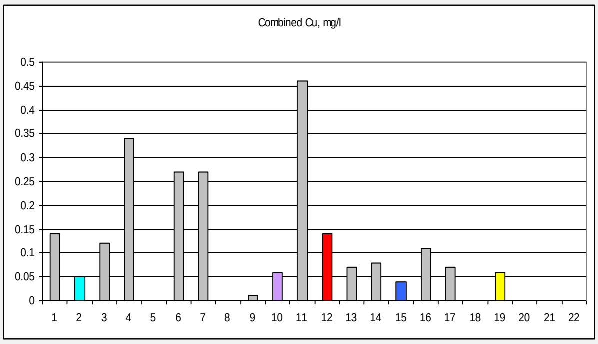

Combined Cl, mg/l
0.12
0.1
0.08
0.06
0.04
0.02
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

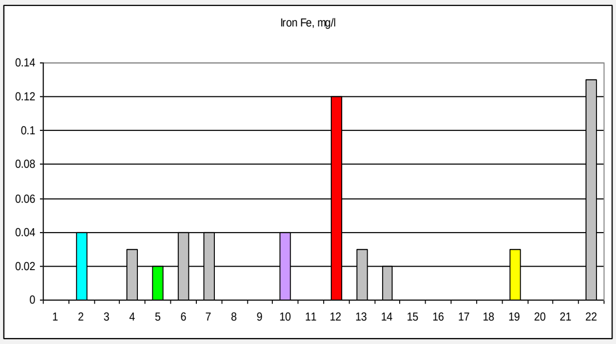

Cyanuric acid CYS, mg/l
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

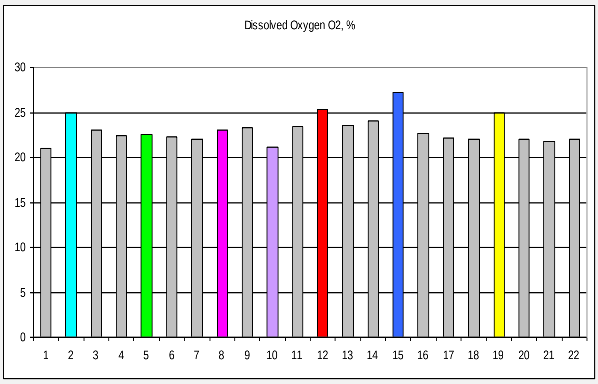

Total Alcalinity CaCO3, mg/l
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

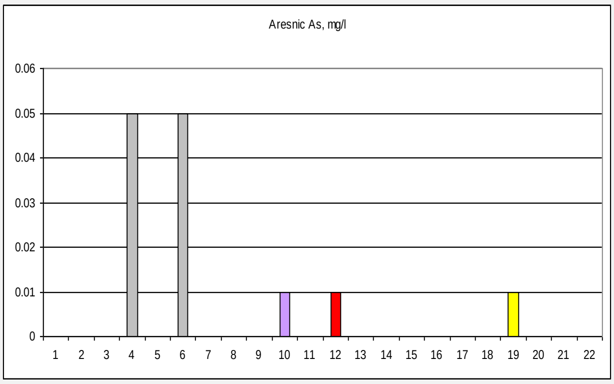

Free Cu, mg/l

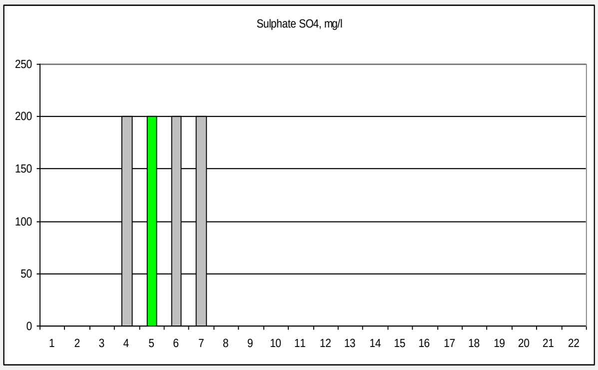

Total Cu, mg/l

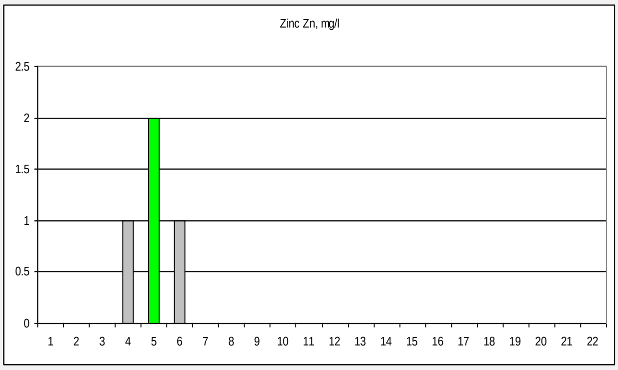

Combined Cu, mg/l

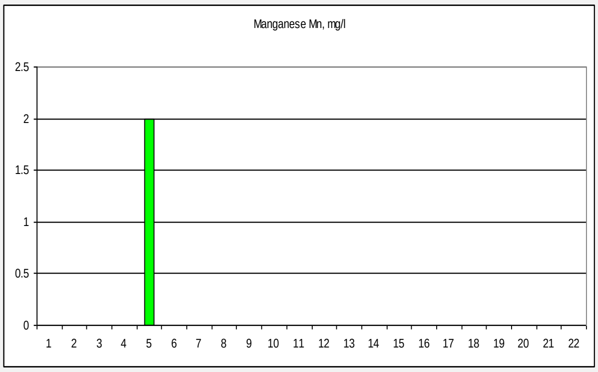

Iron Fe, mg/l

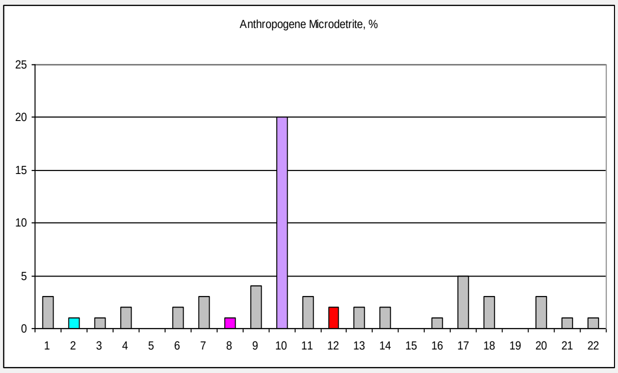

Dissolved Oxygen O2, %


Aresnic As, mg/l


Sulphate SO4, mg/l


Zinc Zn, mg/l


Manganese Mn, mg/l


Anthropogene Microdetrite, %

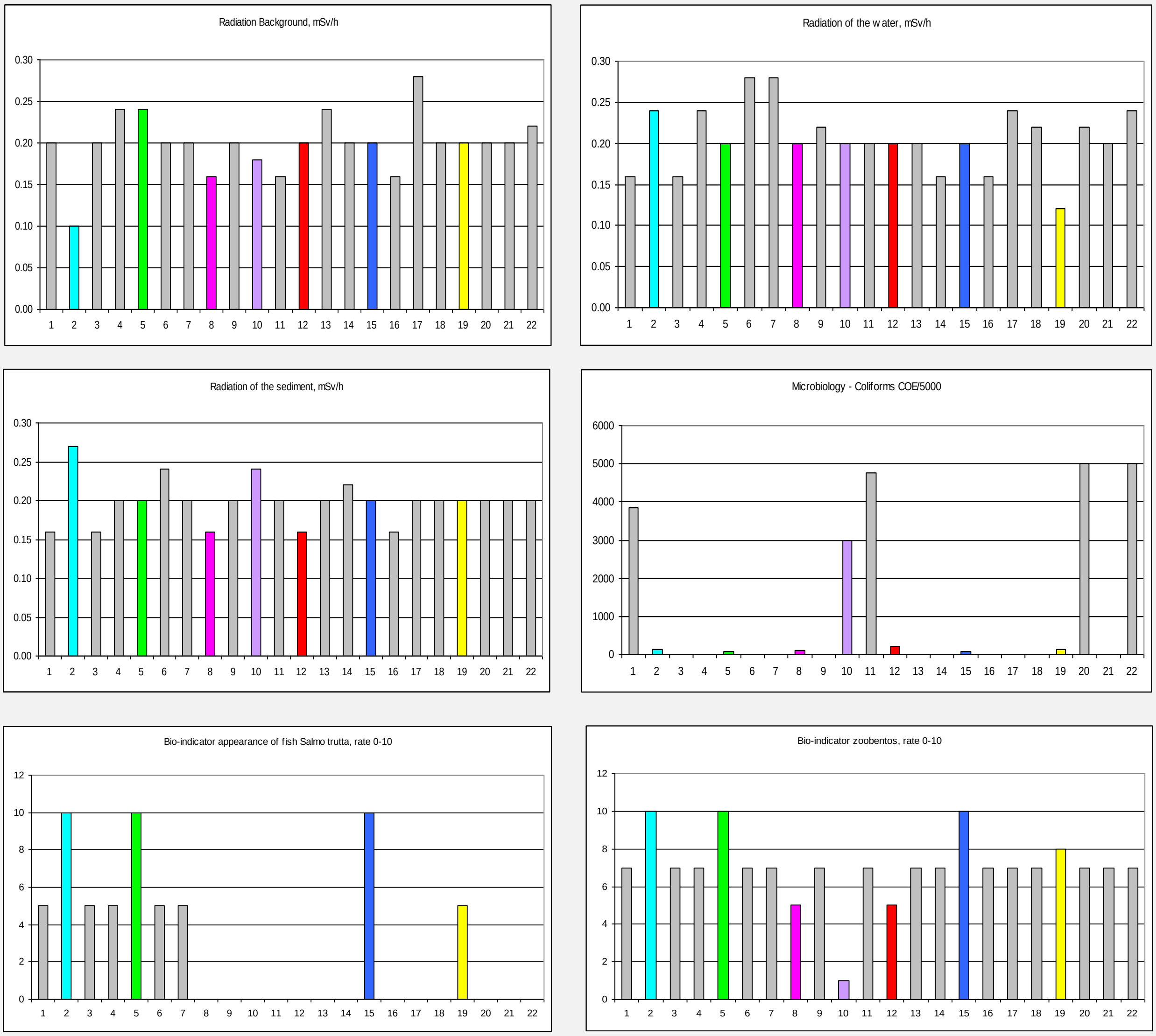


Figure 2. Diagrams of the measured parameters of the water of Struma River. 2-Treklyanska River; 5-Dragovishtitsa River; 8-Bistritsa River; 10-Banshtitsa River; 12-Novoselska River; 15-Eleshnitsa River; 19-Strimeshnitsa River.

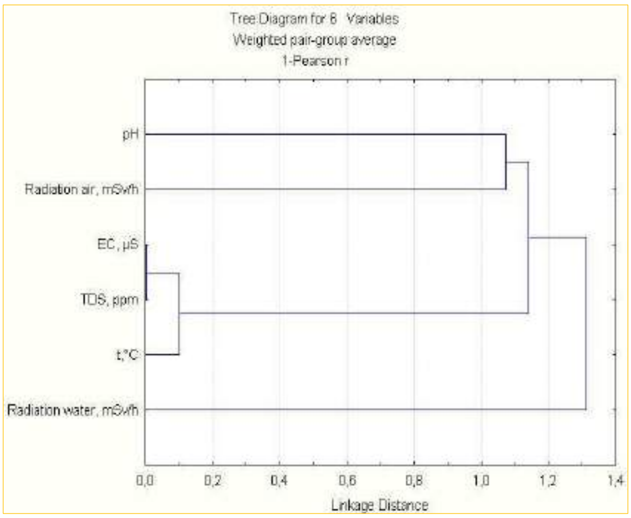


Figure 3. Cluster analyses of the data from winter measurements of the Banshtitsa River.

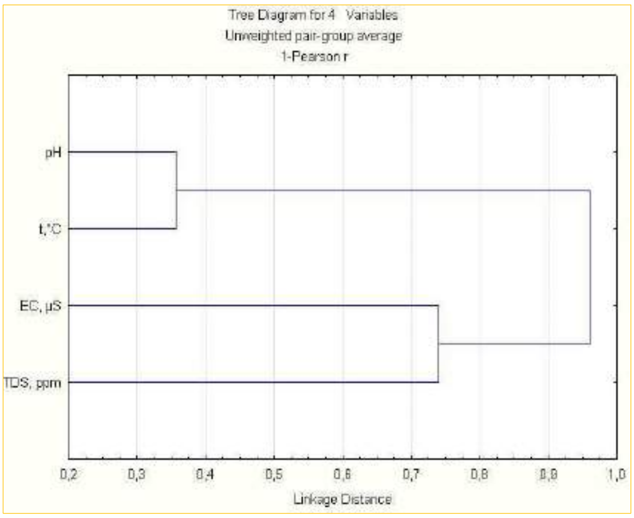


Figure 4. Cluster analyses of the data from summer measurements of the Banshtitsa River.

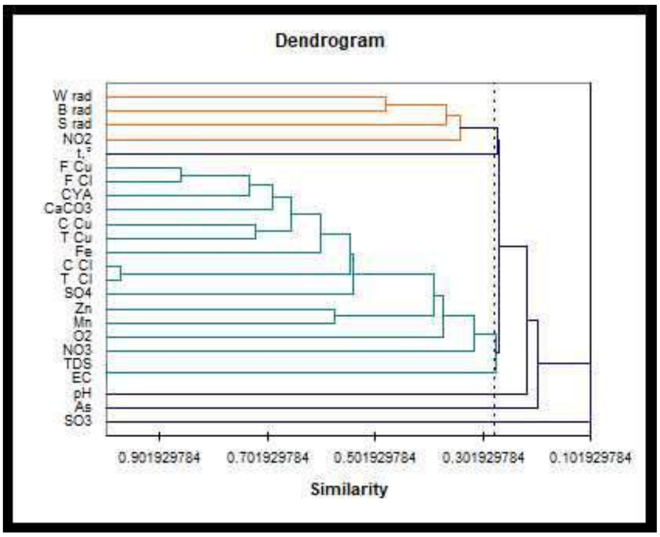


Figure 5. Cluster analyses of the data from summer measurements of the Struma River.

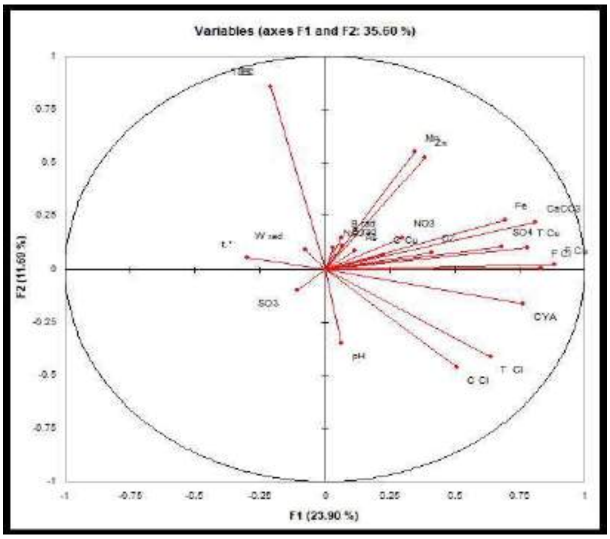


Figure 6. Variables of the data from summer measurements of the Struma River.

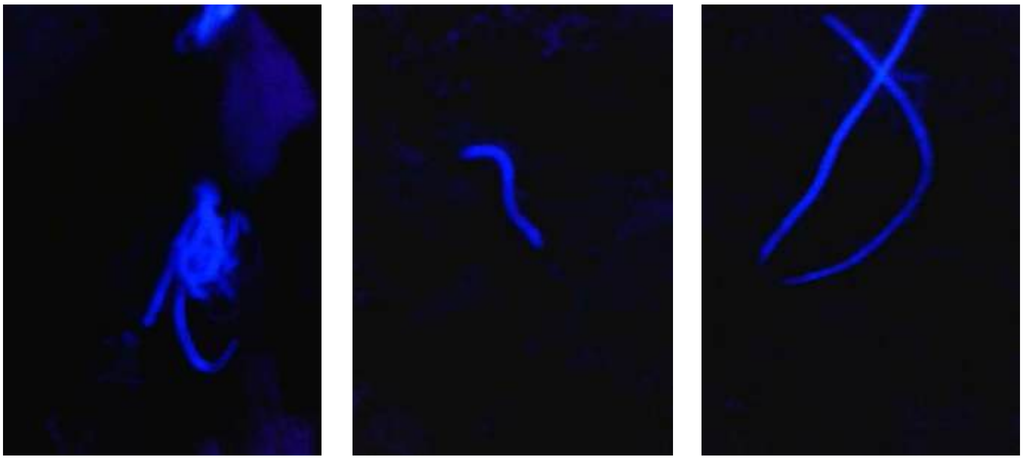


Figure 7. Anthropogenic polyethylene micro-detritus in the sediments along the rivers, fluorescent (blue) light x35.

Left: 1-polyethylene; 2-styropor; 3-textile; 4-quart; 5-textile; 6-ceramics

Right: 1-quartz; 2-white polyethylene cord; 3-yellow polyethylene particle; 4-styropor; 5-metal

Figure 8. Anthropogenic detritus in the sediments and soils along the rivers, white light x 45.

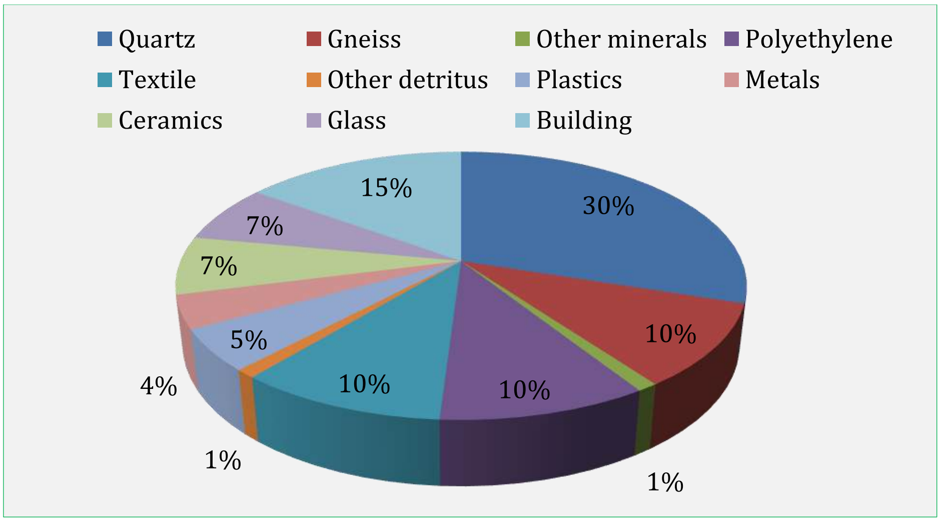


Figure 9. Percentage of the micro-detritus in sediments along the rivers, volume %.

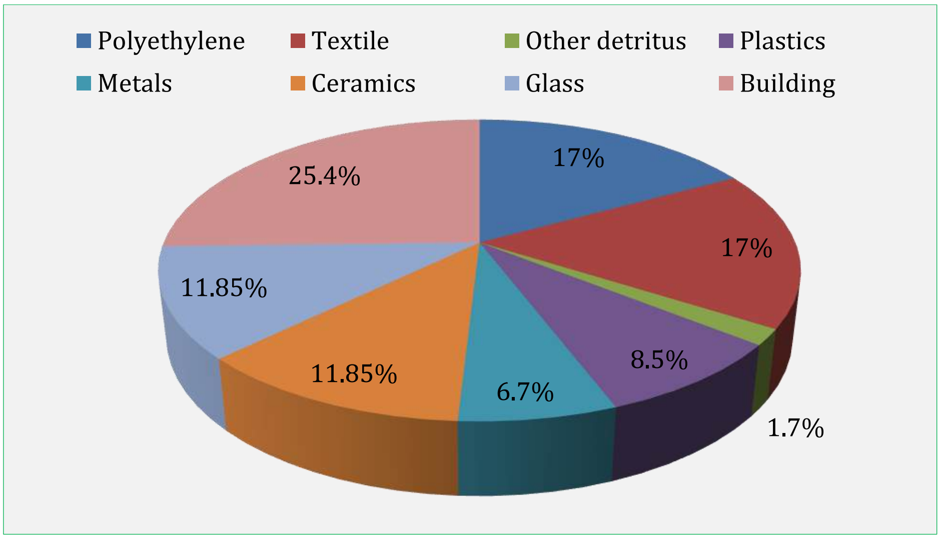


Figure 10. Percentage of the micro-detritus in sediments along the rivers, volume%, with excluded natural mineral content.

Table 1. Mineral composition of the soils from the river's terraces and sediments in Kyustendil region (Number of samples: 9255; number of minerals: 51 (Vitov and Sotirov, 2013).

Mineral	Number samples	Mineral	Number samples	Mineral	Number samples
Anatase	19	Anglesite	10	Andalusite	3
Apatite	396	Arsenopyrite	12	Barite	2125
Bismutite	342	Vanadinite	2	Wolframite	7
Wulfenite	40	Galena	426	Granate	537
Epidotus	328	Gold	1467	Ilmenite	1807
Cassiterite	8	Kyanite	1156	Columbite	3
Corundum	75	Xenotime	432	Leucoxen	16
Limonite	26	Magnetite	278	Malachite	35
Marcasite	53	Martit	372	Copper	2
Molybdenite	37	Monazite	2484	Lead	140
Ortit	359	Pyrite	2049	Pyrolusite	118
Pyromorphite	124	Rutile	1861	Titanite	1974
Staurolite	4	Sphalerite	37	Tourmaline	470
Titanium	545	Thorite	357	Hematite	330
Fluorite	17	Chalcopyrite	24	Cinnabarite	206
Chromite	186	Cerussite	123	Spinel	23
Zircon	3273	Scheelite	824	-	-

Table 2. Some technological characteristics of fruits grown in the Struma valley and its tributaries.

Fruit	**Brix-total sugar, %**	**pH-acidity**	**EC-conductivity, µS**	**TDS-total dissolved solids, ppm**	**Salt, ppm**	**Brix/pH**	**Eh, ORP-redox potential, V**
Apple red	14.7	3.50	1745	1185	878	4.20	0.067
Apple yellow	14.2	3.40	1497	1017	747	4.18	0.049
Apple green	11.5	3.99	1536	1093	767	2.88	0.062
Apricot	15.8	3.00	3350	2300	1780	5.27	0.260
Aronia	31.0	3.60	3000	2050	1580	8.61	0.078
Blackberry	9.6	3.40	3390	1690	1700	2.82	0.335
Cherry red	23.1	3.50	2690	1820	1370	6.60	0.152
Cherry sour	15.9	3.10	2980	2030	1560	5.13	0.192
Cherry white	17.9	3.60	2740	1860	1430	4.97	0.005
Grape red	17.0	3.00	1368	930	680	5.67	0.136
Grape white	17.0	3.30	1378	937	684	5.15	0.146
Melon	9.7	5.97	4930	3310	2370	1.62	0.044
Peach	16.8	3.70	1112	739	527	4.54	-0.063
Pear	13.6	3.60	1468	1012	797	3.78	0.042
Pear Service tree	26.2	3.92	1468	984	733	6.68	0.189
Plum blue	22.7	3.30	1727	1176	880	6.88	0.095
Plum red	15.2	3.16	1017	682	498	4.81	0.158
Plum white	16.6	4.20	1825	1201	935	3.95	0.075
Plum yellow	15.3	3.10	1726	1120	835	4.94	0.116
Pumpkin	5.5	6.34	373	247	177	0.87	0.010
Quince	15.7	2.56	775	517	374	6.13	0.120
Raspberry	15.8	3.20	1383	945	690	4.94	0.065
Watermelon	7.8	5.46	2530	1730	1340	1.43	0.094

Table 3. Some technological characteristics of vegetables grown in the Struma valley and its tributaries.

Vegetable	**Brix-total sugar, %**	**pH-acidity**	**EC-conductivity, µS**	**TDS-total dissolved solids, ppm**	**Salt, ppm**	**Brix/pH**	**Eh, ORP-redox potential, V**
Bean green	4.8	6.38	2530	3550	2890	0.75	-0.017
Beetroot red	9.1	5.30	8930	8260	6900	1.72	0.097
Cabbage	5.4	6.08	5160	3450	2810	0.89	-0.003
Carrot	9.1	6.10	7940	5400	4440	1.49	0.108
Celery leaves	6.2	5.87	1652	1108	962	1.06	0.007
Celery stem	3.1	5.85	1622	8070	7950	0.53	0.238
Celery root	7.1	6.32	8980	6010	5030	1.12	-0.007
Corn	10.0	6.70	2930	1960	1530	1.49	-0.017
Eggplant	5.0	5.16	4540	3040	2460	0.97	-0.003
Onion	7.3	5.68	3350	2240	1780	1.29	0.030
Pepper green	4.8	6.14	4800	2700	2222	0.78	-0.140
Potato	6.3	4.69	874	585	489	1.34	0.020
Spinach	3.9	6.35	8940	4840	5100	0.61	0.188
Tomato green	4.5	4.51	4410	2960	2390	1.00	0.049
Tomato red	5.4	4.37	3890	2610	2100	1.24	0.114
Watermelon	7.8	5.46	2530	1730	1340	1.43	0.094
Zucchini	3.5	6.22	4520	3030	2450	0.56	0.017

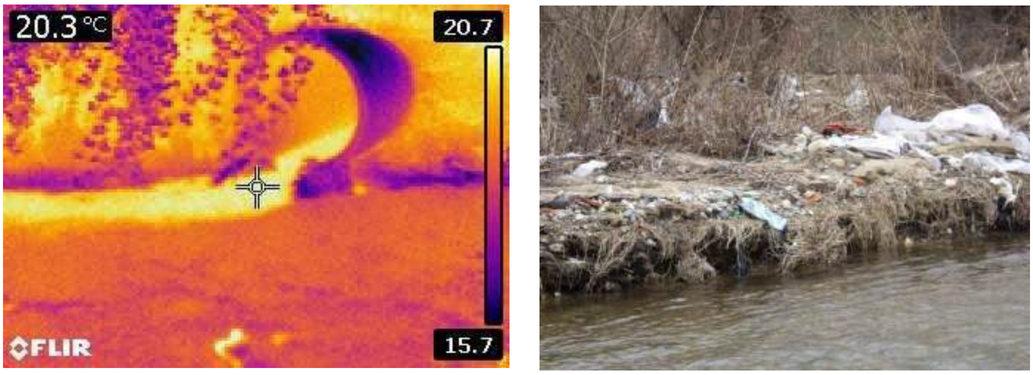


Figure 11. Waste water canal in Dragovishtitsa River–Serbia, right tributary of Struma River and mineral water canal influence on temperature of the river (thermocamera)–left and illegal dumpsites-right.

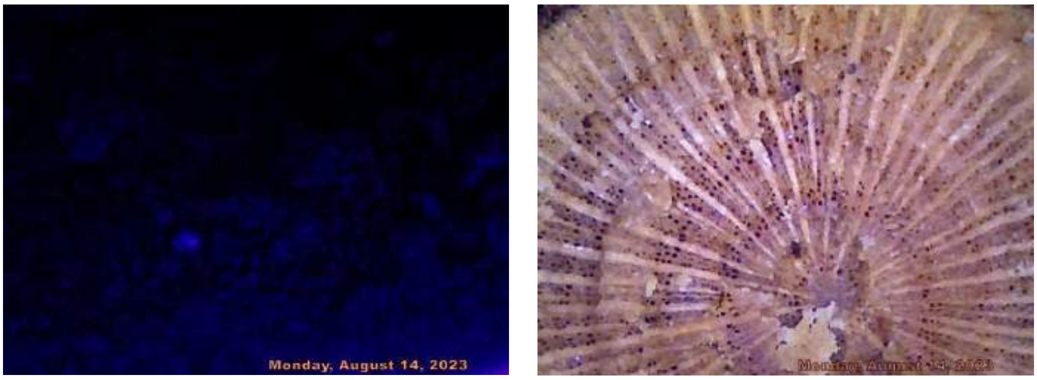


Figure 12. Salt–mineral Halite (left ultraviolet light, right white light, air, x40) in the soil and rooth of died cherry tree, after flooding of the clay minerals in the soil.

Figure 13. Biodiversity of fish and relation with the contamination of Dragovishtitsa River. Bio-indicators for clean water as broun trout fish *Salmo trutta fario* a and fresh water shrimp *Branchiopoda* are missing in in water, contaminated with cyanuric acid or thermal mineral water.

3.2. Discussion

The Struma River before the confluence of its inflows is relatively clean. The acidity of the water is normal for river with a pH=7.10-8.43, with an exemption at the place before and after confluence of Dragovishtitsa River, where its water has pH=9, which is a result of industrial activities related with gold mining in that point. The water at that place has abnormally low conductivity EC=1.49 mS, high concentration of copper Cu=0.34 (Figure 2), Arsenic As=0.05 mg/l, zinc Zn=1mg/l, and sulfates SO_4=200 mg/l. The amount of free, combined and total copper is not high, but systematic irrigation of agricultural areas may enrich the soil with copper and exceed the limit values for soils under Bulgarian State Gazette, No 54/1997. According to this

Gazette, for low acidic and neutral soils, Cu must be under 250-260 mg/kg, but for acidic soils–must be much lower. Free copper in the studied water varies between 0 and 0.8 mg/l, total copper from 0.19 to 0.46 mg/l and combined copper is from 0 to 0.46 mg/l. Higher levels of copper in food and or in pot water can lead to problems with liver in humans (according to World Health Organization WHO, 2004) (Figures 2-6).

Water of Treklyanska River, Dragovishtitsa River, and Eleshnitsa River has relatively clean chemical characteristics in the range of natural contents for Mountain Rivers. Concentration of coliforms of the Serbian part of the Dragovishtitsa River is little more than the Bulgarian part of the river, because of the household canals, but it is in normal rate. Because of the clean water in this river the fish species brown trout (*Salmo trutta fario)* is widely spread. At the point of confluence in Struma River parameters do not change significantly.

At the confluence of Bistritsa River the acidity becomes higher pH = 8.26, which means that Bistritsa River is contaminated probably with washing chemicals from the households. Evidence for this contamination is the high foaming at the point of confluence of the two rivers. Canals for domestic waste water are present. The copper concentration is relatively high Cu=0,80 mg/l. Cyanuric acid is high CYS=12 mg/l. Banshtitsa River is contaminated with almost all studied parameters. Content of coliforms is COE=3000, high nitrate content NO_3=50 mg/l (10 times more that the nitrate directive), high nitrite content NO_2=10. Arsenic As=0.01 mg/l, and anthropogenic micro detritus 10-20% and more.

Water of Novoselska River has high content of cyanuric acid (16 mg/l) (Figure 2). There are no fish species observed. Fishermen also were not observed in the Banshtitsa, Bistritsa and Novoselska Rivers. Strumeshnitsa River has high concentrations of nitrate NO_3=25 mg/l, nitrite NO_2=10 mg/l. The reason is that the area has highly developed agriculture. There are fish species, but *Salmo trutta fario* is absent. River sediments and alluvial soils are contaminated with various anthropogenic micro detritus (microscopic fragments of human waste) such as polyethylene (10%), plastics (5%), textile (10%), ceramics (7%), metals (4%), building materials (15%), glass (7%), coal, ash, rubber, paper, styropor (1% each), and others (Figures 7, 8, 9, 10).

Anthropogenic micro-detritus is widely spread in the sediments and soils and measures for this contamination must be taken. Such as localization, more strict regulations of illegal dumpsites and cleaning of river beds and shores. Quality of the water and soils along the studied rivers influences directly on the quality of the crops, livestock, produced food, and fish species. For example as a results of nitrogen fertilizer abuse traces of nitrates and nitrites have been established in different vegetables-tomatoes and cucumbers of local producers. The bio-indicator fish *Salmo trutta fario* disappears in places with high concentration of cyanuric acid. Figures 11-12 present additional information about the illegal dumpsides, waste channels and salinized soils in the srudied area.

Through usage of microscope with fluorescence (blue) light it was established polyethylene micro detritus in soils, sediments, but also additional investigations established microplastics in nylon-packaged food as cheese, yellow-cheese, sausages, and in dog and bird excrements. Polyethylene fragments may become a part of a food chain and might cause strangling of the animals, occlusion of the digestive tract, trauma of the internal organs, necrotic and inflammation of the intestines, intoxication of man and animals. Presence of the anthropogenic micro-detritus might become poor the soil and might change the soils structure. Pure plastics have low toxicity due to their insolubility in water and because they are biochemically inert, due to large molecular weight. Plastic products contain a variety of additives, some of which can be toxic. For example, plasticizers like adipates and phthalates are often added to brittle plastics like polyvinyl chloride in order to make them pliable enough for usage in food packaging (Wright *et al.,* 2013).

Table 1 gives information about mineral content of the soil and sands in the region and some technological and agroecological parameters of the agricultural crops and instead that the soil and sediments are rich of elements and minerals which are risk for the environment, the crop is ecologically clean and non-contaminated. Some other authors worked on economic assessment of different fruit cultivars topics are also Dimitrova *et al.,* (2021), Sotirov *et al.,* (2018), and Todorova (2012). The sustainable fertilization is used in the region by the methods described by Baldi and Toselli (2013) and Zdravkova and Krishkova (2023). Tables 2 and 3 present the results of the measurements of the technolgical and ecological parameters of fruits and vegetables grown in the studied area and their juices. All tested varieties and their juices have low radioactivity in accordance with the regulations. To some extent, there is a relationship between the common radiation background and the radioactivity of the fruit. With few exceptions, the radioactivity of the juices directly depends on the radioactivity of the fruits, with a slight decrease in the values in the juice in most cases. The sulfates SO_4^{2-} in the juice of all apple varieties, vary between 200 and 400 mg/l or about 300 mg/l average. The measured values are minimal, according to the scope of the applied test, and the sulfates are probably part of the organic and mineral substance of the apples, and it is not a result of plant protection or environmental pollution of the area. Sulfites SO_3^{2-}, lead Pb, arsenic As, nitrates NO_3^- and nitrites NO_2^- are not detected by the applied test methods. Manganese (Mn) and zinc (Zn) have constant contents, because of this reason it is assumed that they are also part of the natural chemical composition of apples, and not the result of environmental pollution. Manganese content in apples of 2,37 mg/100 g and zinc 0,88 mg/100 g have been reported by Omba *et al.,* (2020), i.e. the contents of these two elements measured by in present study (Mn=2 mg/l and Zn=1 mg/l) are part of the nutrition composition of apples and cannot be claimed for ecological pollution.

4. Conclusions

As a result of this vast investigation, the main conclusion is: the most widespread sources of contamination in the studied cross-border European region between 4 European countries (Bulgaria, Serbia, North Macedonia, and Greece) are the illegal landfills, dumping of waste and household waste water canals, result of the living process of the local population without respect to any National and EU legislation. Equal to this harm is the poor work of municipal and governmental authorities towards waste management of the area. Second source of contamination is farming and construction activities. Usage of fertilizers is widespread in the area during spring and summer period. Farming and construction waste dumped illegally in river beds also contaminates the water and soils in the area. The region is not industrially developed and industry is not the main pollutant of the area.

It is established that population of the fish species closely relates to contamination of the water. Contaminated rivers do not have any fish species (Figure 13). Feeding streams bring contamination into Struma River and decrease population of some fish species such as brown trout fish (*Salmo trutta fario*)*.* This brown trout fish (*Salmo trutta fario*) disappears in water, contaminated with cyanuric acid (Novoselska and Bistritsa Rivers) or in water contaminated with thermal mineral water (Banshtitsa River).

In conclusion, it can be said that in agroecological view, the studied apple and cherry varieties are of high quality and ecologically clean.

Declarations

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