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A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Determination of anthropogenic impact on the Siret River and its tributaries by the analysis of attached algae

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Abstract

The article is devoted to the determination of anthropogenic impact on the Siret River and its tributaries (the Sukhyj, the Mikhidra and the Malyj Siret Rivers). The taxons of attached algae were determined in this case. Then they were distributed in the saprobity groups and the correlation of each group was found. It was necessary to identify the stage of ecological regress on each site of the researched basin. The data about the ecological regress can be used as primary information on the aquatic ecosystem state for conducting the further researches. The next step of the investigations was counting of the saprobity index by Pantle and Bukk in Sladechek modification for classification of quality status of water in the researched basin.

Key words: *anthropogenic ecological regress, attached algae, bioindication, phytoperiphyton, saprobity index*

INTRODUCTION

The ecological state of surface waters is one of the most urgent problems all over the world. The anthropogenic impact on surface waters is increased every year. It causes the deterioration of quality state of surface water resources and the state of the aquatic ecosystem as a living system. This is the reason why more and more countries use the ecosystem approach in investigation of water bodies. That means that water body is perceived not only as a source of water for humans, but also as a habitat of many creatures that are also the elements of the quality of water sources. The formation of aquatic ecosystems is caused as a result of processes occurring in the catchment basin and throughout the river. We cannot fully assess the condition of aquatic ecosystem by means of chemical analysis of water quality. That is why the biological parameters are very important to know.

In the present research the phytoperiphyton organisms have been used as bioindicators of the aquatic ecosystem state. The Siret is a mountain river with a fast current. That is why the attached algae is the most appropriate group of algae for ecological researches in such conditions.

The main goal of the investigation is the assessment of Siret River and its tributaries water quality by the biological parameters and study the opportunity of the application of the concept of the anthropogenic ecological regress as the previous assessing of aquatic ecosystem's state.

STUDY SITES

The object of the investigation is the Ukrainian part of the Siret River basin.The Siret River is the left tributary of the Danube River (Fig.1).

The upper part of the basin is situated in the Eastern Carpathians and in Bucovinian foothill upland. The most length of the basin is 62 km, the middle width – 23 km. The riverbed is meandering, moderately branched. The spring flood usually begins at the

Fig. 1. The Siret River as the Danube tributary (from the http://en.wikipedia.org/wiki/Danube)

beginning of March. The highest level of it is observed in the third week of March and reaches the level of 0.4–1.3 m. The season distribution of river runoff is irregular: half of the river runoff falls on spring (42–45%). The 10–12% of annual runoff falls on winter. The maximum of water consumption of spring meltwater is 40–50 $m^3 \cdot s^{-1}$ and in summer (from rains) – 50–60 $m^3 \cdot s^{-1}$. The highest value of water consumption from the Siret River was 816 $m^3 \cdot s^{-1}$ till all the period of the observations. The lowest value of water consumption was 0.1 $m^3 \cdot s^{-1}$. The ice regime of the river is unstable. Its average duration is 90 days. The river is used as a source of hydroelectric power, and in some areas it is used for timber floating.

METHODS AND MATERIALS

The substrate samples were selected at 8 sites of the Siret River and its tributaries (the Sukhiy, the Mikhidra and the Maliy Siret rivers) (Fig. 2).

Sampling sites were located up and downstream of the settlements as one of the factors of anthropogenic impact on the river basin.

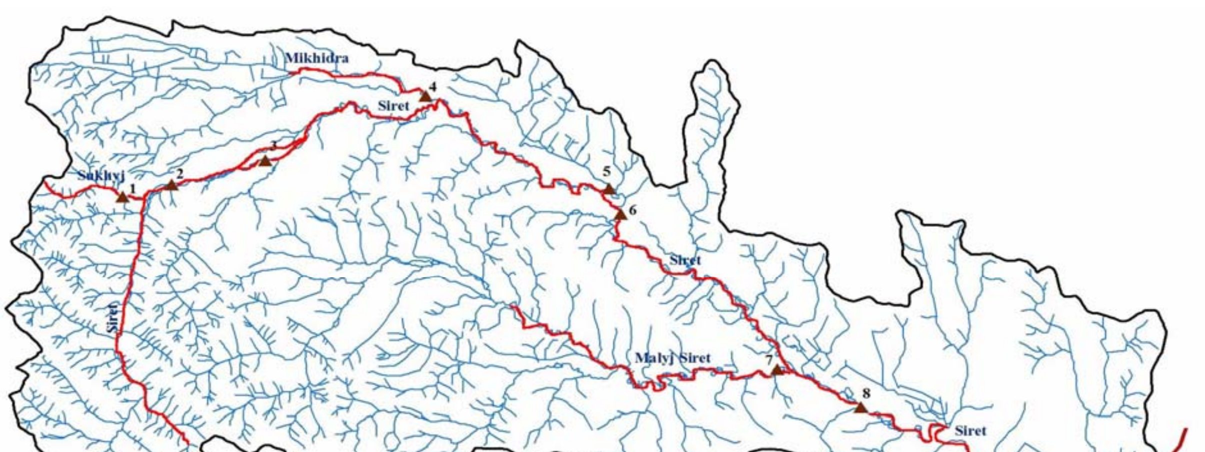

Fig. 2. The Siret River basin and sites of sampling (drawn by ArcMap program)

MATERIALS AND METHODS

To determination of taxons of attached algae and their affiliation to some saprobic the generally accepted methods have been used.

Sampling were taken from the rock substratum of the river-bed $1m^2$. The samples were preserved with 4% formalin solution. The microalgae were examined in magnification of 500 x for species identification. For reliable identification of some diatoms (genera *Achnanthes, Fragilaria, Navicula, Nitzschia,* etc.), subsamples were treated with 30% hydrogen peroxide, heated, and mounted on slides. The slides were subsequently examined at 800 x. Taxonomic identity had been determined by biological determinants.

The next step was to counting the saprobic index of the Siret River water and its tributaries by attached algae. It was done by means of the following formula:

$$S = \frac{\sum sh}{\sum h}$$

where:

S – is the saprobity index;

s – the saprobity value of each species of algae,

h – the number of each species in the sample.

The meaning of the saprobity index in different sites of the researched basin was applied to define the category of water quality by biological indicators. The classification of 5 categories and 9 discharges of quality was used for the determination of the categories of water quality (by Romanenko and others). The ecological and sanitary classification consists of the data of all representative hydrochemical, hydrophysical and hydrobiologycal indicators. One of the hydrobiological parameters of water quality according to this classification is the saprobity index (Tab. 1).

Table 1. Classification of water quality by hydrobiological parameters

Category of water quality	Discharge of water quality	Saprobity index value
i excellent	1 excellent	<0.5
ii pure	2a very pure	0.5–1.0
	2b sufficiently pure	1.1–1.5
iii moderately	3a moderately pure	1.6–2.0
	3b slightly contaminated	2.1–2.5
iv contaminated	4a moderately contaminated	2.6–3.0
	4b heavily contaminated	3.1–3.5
v dirty	5a rather dirty	3.6–4.0
	5b very dirty	>4.0

Source: classification by Romanenko V., Oksiyuk O.

Comparison of the obtained data with the categories of water quality gives the opportunity to assess the ecological state of the river.

The next step of the research was counting the percentage of the organisms from different saprobic groups for the determination of the stage of anthropogenic regress of the river ecosystem.

The anthropogenic influence expressed in the additional getting of organic and inorganic matter into water bodies results in work increase on trophic chains. The natural balance between abiotic and biotic components is being broken. There is a simplification of the ecological community relations with the environment and its institutional degradation that leads to ecological regression as a result

The anthropogenic ecological regress is shown in decreasing of species diversity, simplification of interspecies relationships, significant increase in the intensity of metabolism of biocenosis etc.

The attached algae is considered as to be very effective for the assessment of water bodies quality because its formation hardly depends on the random local pollutions. The main feature of this long successions is the poorness of its species composition and the α – and β–α – saprobic species become dominant in the aquatic ecosystem.

There are the types of ecological regress: 1) anthropogenic ecological stress – 15–43 species of the attached algae are defined in the sample and they are the representatives of pure water; 2) anthropogenic ecological stress with the elements of ecological regress – 10–20 of the attached algae are defined in the sample and the frequency of occurrence of representatives of *Fragillaria*, *Diatoma*, *Navicula* families are increased; 3) anthropogenic ecological regress – further decline in species diversity of phitoperiphyton (5–20 species) and the dominants are α – and β–α – saprobic species like *Navicula*, *Oscillatoria*, *Nitzschia*.

We believe, that this parameter is convenient for the fast assessment of the aquatic ecosystem state, because it needs only the data of species composition and saprobity of species. The data of ecological regress can be used as the primary information about the ecosystem state and according to them further researches can be conducted.

RESULTS AND DISCUSSION

For the whole period of researches (2008–2011) 143 species of the phytoperiphyton algae were identified. 89.5% of them belonged to the *Bacillariophyta* division, 5.2% – to the *Cyanophyta*, 4.2% – to the *Chlorophyta* and 0.7% – to the *Euglenophyta* divisions (Fig. 3).

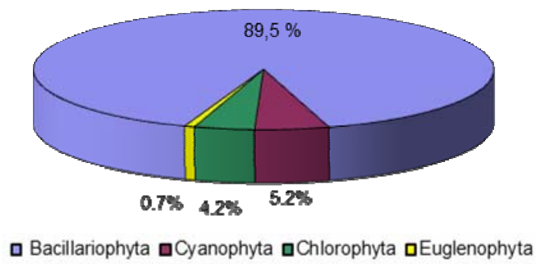

Fig. 3. Percentage of the phytoperiphyton algae in the Siret River basin; source: own study

There were four predominant divisions of algae in the basin communities: diatoms (*Bacillariophyta*), green algae (*Chlorophyta*), blue-green algae (*Cyanophyta*) and euglen algae (*Euglenophyta*). Diatoms were the main group of algae community for all sites of the basin. The dominant diatoms were: *Navicula* (25 species), *Achnanthes* (10 species), *Gomphonema* (16 species), *Diatoma* (2 species), *Cymbella* (20 species), *Stauroneis* (2 species), *Nitzschia* (12 species), *Eunotia* (1 species). The mostly met among them were such species as: *Navicula cryptocephala*, *N. cincta*, *N. minima*, *Achnantes lanceolata*, *A. linearis*, *A. microcephala*, *Gomphonema constrictum* var. *capitatum*, *G. acuminatum* var. *trigonocephalum*, *Meridion circulare*, *Cocconeis pediculus*, *Stauroneis anceps*, *Cymbella cistula*, *C. alpine*, *C. sinuate*, *Diatoma vulgare*, *Eunotia exiqua*.

Cyanophyta were presented by 9 species from 8 genus and 4 families. The most numerical of them were *Microcystis*, *Mesotaenium*, *Gloeocapsa*, *Calotrix*, *Rhabdoderma*. The most frequement among them were such species as: *Microcystis aeruginosa*, *Gloeocapsa turgida*, *Mesotaenium macrococcum*, *Calotrix parientina*, *Rhabdoderma lineare*.

The green algae were presented by single organisms and the most numerous of them were *Closterium* (3 species), *Cosmarium* (2 species), *Ulotrix* (2 species): *Ulotrixaequalis*, *U. subtilissima*, *Cosmarium botrytis*, *Closteriumvenus* etc.

After the determination of the algae taxons the preliminary analysis of aquatic ecosystem was done by the carried out of the sites with different level of anthropogenic ecological regress (Tab. 2).

Table 2. The stage of the anthropogenic regress of the Siret River basin ecosystem

Name of the site	Number of species	The average saprobity	The stage of the anthropogenic regress
The Sukhiy River	52	**β**(34.6%) **o**(8.0%)	the anthropogenic environmental stress
The Siret River (Beregomet village)	76	**β** (29.0%)	the anthropogenic environmental stress
The Siret River (Lucavtsy village)	33	**β** (27.0%) **β-o** (9.0%)	the anthropogenic environmental stress
The Mikhidra River	28	**β** (46.2%)	the anthropogenic environmental stress
The Siret River (Storozhinets town)	43	**β** (34.8%) **α** (11.6%)	the anthropogenic environmental stress with the elements of the regress
The Siret River (Storozhinets town downstream)	29	**β** (34.8%) **α** (10.0%)	the anthropogenic environmental stress with the elements of the regress
The MaliySiret River	34	**β** (32.4%) **o** (8.0%) **x** (8.0%)	the anthropogenic environmental stress
The Siret River (Kamyanka village)	50	**β** (36.0%) **α** (16.0%)	the anthropogenic environmental stress with the elements of the regress

Source: own study.

The taxonomic analysis shows that only three sites of the basin are related to the ecosystems with the elements of the anthropogenic ecological regress. Two of them are situated near the town (Storozhinets) and the third is situated downstreams and it's the lowest point of the monitoring near the Ukrainian-Romanian border (Kamyanka village). These monitoring points were characterized by higher frequency of the species occurring in moderately polluted and contaminated waters. The most numerous of these species were: *Nitzschiapalea*, *Nitzschiaacicularis*, *Naviculacryptocephala*, *Naviculacincta*, *Diatomavulgare*, *Fragillariavierences*. The total cell number of these species increased downstream (Fig. 4, Fig. 5).

Beregomet village is the highest point of sampling. It is situated in mountains and it is not very populous. The anthropogenic pressure on the aquatic ecosystem in this area is not very large. Accordingly, the number of the representatives of α – and β–α – saprobity groups of algae there will be not high. On this site of monitoring the number of*Naviculacincta* was 250–300 cells·m^{-2}, *Naviculacryptocephala* – 1800–2300 cells·m^{-2}, *Nitzschiapalea* – 750–1000 cells·m^{-2}, *Nitzschiaacicularis* – 500–700 cells·m^{-2}, *Diatomavulgare* – 1000–1600 cells·m^{-2}.

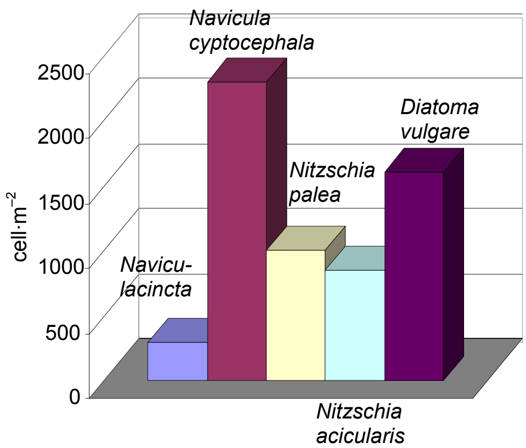

Fig. 4. The abundance of attached algae of moderately polluted and contaminated waters in the Siret River (Beregomet village – the highest site of monitoring); source: own study

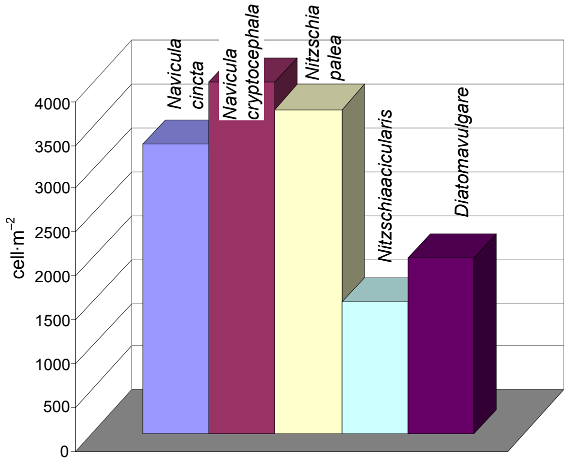

Fig. 5. The abundance of attached algae of moderately polluted and contaminated waters in Siret River (Kamyanka village – the nethermost site of monitoring); source: own study

Kamyanka village is the lowest downstream point of the sampling. It is situated on the plate territory and it is more populous. The current on this side is slower than in the mountain sides upstream. The number of *Navicula cincta* was 3000–3300 cells·m^{-2}, *Navicula cryptocephala* – 2000–2500 cells·m^{-2}, *Nitzschia palea* – 3500–3800 cells·m^{-2}, *Nitzschia acicularis* – 1000–1500 cells·m^{-2}, *Diatoma vulgare* – 1300–1700 cells·m^{-2} on the site of monitoring.

The next step was counting the saprobic index of the water of Siret River and its tributaries by the attached algae and their correlation with categories of water quality (Tab. 3).

Table 3. Categories of water quality of the researched part of the Siret River basin (from the whole period of investigation)

Sites names	Saprobity index	Category of water quality
The Sukhiy river	1.45	II (2b) pure (sufficiently pure)
The Siret River (Beregomet village)	1.45	II (2b) pure (sufficiently pure)
The Siret River (Lucavtsy village)	1.38	II (2b) pure (sufficiently pure)
The Mikhidra river	1.45	II (2b) pure (sufficiently pure)
The Siret River (Storozhinets town)	1.48	II (2b) pure (sufficiently pure)
The Siret River (Storozhinets town downstream)	1.70	III (3b) moderately (slightly contaminated)
The MaliySiret River	1.57	III (3b) moderately (slightly contaminated)
The Siret River (Kamyanka village)	1.80	III (3b) Moderately (slightly contaminated)

CONCLUSIONS

The obtained results allow to assess the quality of the researched water by the categories of quality for biological parameters. The researched basin of the whole period of investigation is related to the pure (sufficientlypure) quality class on average.

The quality class became worse –moderately downstream (slightly contaminated). It was shown by the results in sites below Storozhinets town. The results confirm the existence of the elements of the ecological regress. The negative changes that have occurred in the quality status of the Siret river basin ecosystems are reverse and the timely solving a number of administrative and household tasks could give to aquatic ecosystem the chance to recover to reference conditions.

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Określenie antropogenicznych oddziaływań na rzekę Siret i jej dopływy poprzez analizę osiadłych glonów

STRESZCZENIE

Słowa kluczowe:*peryfiton roślinny, osiadłe glony, indeks saprobowości, bioindykacja, antropogeniczna degradacja ekologiczna*

Artykuł poświęcony jest określeniu oddziaływań antropogenicznych na rzekę Siret i jej dopływy (Suchy, Mikhidra i Mały Siret). Oznaczano taksony osiadłych glonów. Przy użyciu korelacji przypisano je do grup saprobowości. Niezbędne było ustalenie stopnia ekologicznej degradacji dla każdego stanowiska badanej zlewni. Dane o degradacji mogą służyć jako wstępna informacja o stanie ekosystemu wodnego dla dalszych badań. Kolejnym etapem prac było obliczenie wskaźnika saprobowości wg Pantle i Bukka w modyfikacji Sladečka celem dokonania klasyfikacji jakości wód badanej zlewni.