IMPACT OF EUTROPHICATION AND INDUSTRIAL POLLUTION ON BIODIVERSITY EVOLUTION OF THE LACUSTRINE ECOSYSTEMS FROM THE ROMANIAN SECTOR OF THE DANUBE RIVER

*OLIVIA CIOBOIU *, CARMEN - MĂDĂLINA CISMAȘIU ***

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The construction of a 1,158 km long dike on the Romanian course of the Danube River led to the disappearance of more than 400,000 hectares of lakes, ponds, marshes. The Danube River was partially diked between 817 and 665 km, and its floodplain is characterized by structural and functional diversity of lacustrine ecosystems. This sector, covering 56,425 ha, is a sample of the former floodplain, which preserves biocoenotic structures specific to wetlands. Eutrophication is one of the fundamental factors affecting the structure and functionality of these lacustrine ecosystems. Their benthos facies consist of a thick layer of organic silt and vegetal detritus, explaining the clogging tendency of the lakes. The main groups of benthic invertebrates are Oligochaeta, Chironomidae, Plecoptera, Bivalves. Gastropods represent the dominant group of the benthic production with 37 species. Thus, the anthropic impact on indigenous microorganisms demonstrates their involvement into the biogeochemical cycles, by: chemical-bacterial solubilisation of industrial wastes and supply of metal ions from industrial effluents; concentration and removal of heavy metals from industrial waste waters. Acidophilic microorganisms present in soil and water, by the mineralization of organic substances, ensure circulation of organic matter, releasing mineral elements used by plants for their nutrition.

Key words: eutrophication, lacustrine ecosystems, Danube River, invertebrates, microorganisms

INTRODUCTION

It is known that, along the Romanian Danube River sector, it was constructed a 1,158 km long dike that separated the main channel of the Danube River from its flood-prone area. The construction of the dike conditioned the disappearance of lakes, marshes and bogs over a surface of 400,000 ha as well as changed the ecology of that vast territory. Between 817 and 665 rkm, the Danube River was partially diked and this river corridor is characterized by high structural and functional diversity of the lacustrine ecosystems located in southern Romania. This sector, our study area affected by industrial activities and covering 56,425 ha is characterized by the disappearance of floodplain – channel connectivity, however, it still preserves the biocoenotic structures specific to wetlands (CIOBOIU and CISMAȘIU 2016). The main ecosystem components in the area between the localities Cetate and Dăbuleni in the sector of the Danube Floodplain are: lakes (Maglavit, Desa-Ciuper-ceni, Bistreț), ponds (Manginița, Țarova, Balta Lată), brooks (Milu's brook), and series of swamps and side channels. These ecosystems are subject to anthropogenic eutrophication process and industrial pollution.

The acute pollution of the river produced ecological changes in the structure and functionality of the lacustrine ecosystems in this sector. As a result of eutrophication, water chemistry is characterized by high levels of nutrients (NO_3^-, PO_4^{3-}) which explains the mass development of aquatic and paludous macrophytes, as well as of phytoplankton. This process induced by the increasing quantities of inorganic and organic nutrients transported by the river waters determined the modification of natural evolutionary tendency of all biocoenotic structures. Due to the enhanced eutrophication, the lakes are in an advanced process of the biological clogging. The clogging of the lakes leads to the appearance of these marshlands covered by paludous vegetation, reduction of depth and surface, algal blooms that harm fish and human health (GIANFREDA and RAO

* The Oltenia Museum, Craiova, Section of Natural Sciences, Street Popa Şapcă, No. 8, 200416, Craiova, Romania, e-mail address: oliviacioboiu@gmail.com, cioboiu.olivia@yahoo.com (corresponding author)
** Institute of Biology Bucharest, Department of Microbiology, Romanian Academy, Street Splaiul Independenței, No. 296, 060031, Bucharest, Romania, e-mail address: carmen.cismasiu@ibiol.ro, madalinabio@yahoo.com

2004, SANDU and BLOESCH 2010, BREZEANU et al. 2011, PANDEY and FULEKAR 2012).

MATERIALS AND METHODS

In view of assessing the hydrobiological characteristics, based on the data published (CIOBOIU 2008, BREZEANU et al. 2011, CIOBOIU and BREZEANU 2014) and on our own research we assess the lacustrine ecosystem biodiversity of the studied sector. In order to render the physical-chemical characteristics of water and the planktonic and benthic structures pertinent samples were taken.

In order to establish the chemical composition of the organic material, which is matured in the mortar, the samples were dried at about 70° C. The experimental mineralization process were performed to determine the concentrations of the metallic ions from these solution and were conducted in four steps: (1) the Teflon tube is placed 1 g of dried and ground organic material; (2) 65 % nitric acid, 37 % HCl and hydrogen peroxide are added to the tube; (3) 5 ml of the standard solution of 5 ppm is added to each sample and made up to the mark with distilled water in a 25 ml volumetric flask; (4) the calibration solutions in the ascending order of concentration and the blank sample (zero) are analysed to determine the calibration curve at different wavelengths of the DR 2000 and Avanta (GBC) atomic absorption spectrophotometer.

RESULTS

As far as pH values as an important characteristic of water chemistry of the eutrophization of ecosystems, they vary between 6.5 and 8.5 (slightly alkaline). The large amount of nitrates and nitrites is induced by the nutrient (1.5 - 7 mgl^{-1} NO_3^-; 0.007 - 0.161 mgl^{-1} PO_4^{3-}) input as mineral and organic fertilizers are intensively used in the neighbouring agricultural fields. Among the cations, calcium (Ca^{2+}) was registered that originates from the sedimentary rocks found at the bottom of the lakes and in the treatments applied to the agricultural plots (CIOBOIU 2014).

The structure of planktonic and benthic biocoenoses**.** The effect of the eutrophication process is manifested through the excessive development of phytoplankton and paludous and aquatic macrophytes. Bacillariophyceae and Chlorophyceae are dominant groups within phytoplankton, while Cyanophyta intensively develop in summer. The most common species are: *Diatoma elongatum, D. vulgare, Synedra acus, S. ulna, Amphora ovalis*, *Ceratoneis arcus*, *Gyrosigma acuminatum*, *Scenedesmus quadricauda*, *S. acuminatus, Pediastrum duplex*, *P. boryanum*, *P. simplex, Cymatopleura solea, Navicula cineta, Cymbella affinis, C. lanceolata, Microcystis aeruginosa, Euglena viridis*, having an average numerical density of over 80,000 specimens/l. Paludous and aquatic macrophytes occupy an important place in the bioeconomy of ecosystems, the dominant species being *Phragmites communis*, *Typha angustifolia*, *Nuphar luteum*, *Nymphaea alba*, *Rorippa amphibia*, *Poygonium amphibium*, *Iris pseudacorus*, *Equisetum arvense*, *Euphorbia palustris*, *Scirpus lacustris*, *Carex riparia*, *Ranunculus aquatilis*, *Salvinia natans*, *Stratiotes alloides*, *Myriophylum spicatum*, *Hydrocharis morsus-ranae* (DIHORU and ARDELEAN 2009). An overall evaluation of the biomass production showed that there can be obtained 85,200 kg/ha $^{-1}$/year^{-1} wet biomass. It is a proof of the trophic capacity of the ecosystems (CIOBOIU and CISMAŞIU 2016).

As well as phytoplankton, zooplankton is an important part of the organic production from biomass. Its development is correlated with that of phytoplankton, the latter being the main food source of zooplankters. The dominant groups are rotifers, copepods and cladocerans (BREZEANU et al. 2011). In case of rotifers, the numerical density of which exceeds 86 thousand specimens/l, the dominant species are: *Brachionus angularis, B. calyciflorus, Keratella cochlearis, Polyarthra vulgaris, P. major, Filinia longiseta, Asplanchna priodonta, Synchaeta pectinata.* Copepods that have a significant contribution to the production of zooplankton (over 20,000 specimens/l) are often represented by the following species – *Acanthocyclops vernalis, Cyclops vicinus, Eudiaptomus gracilis, Mesocyclops leukarti*. Cladocerans are a group with a large share in the zooplankton of eutrophic lakes. The dominant and common species are: *Diaphanosoma brachiurum, Moina micrura, Bosmina longirostris, Leptodora kindi, Sida cristalina, Daphnia cucullata, Chydorus sphaericus, Leydigia acanthoscelidis*. Benthos floodplain structure is determined by the structure of benthic facies. Macrophytes that grow excessively in most lakes and ponds are the main cause of the accumulation of large amounts of detritus so that most of the bottom surface is made of a muddy and detritic facies. The main benthic groups are Oligochaeta (dominant species *Limnodrilus* sp., *Peloscolex ferox, Stylaria lacustris, Branchiura* sp.), Chironomida (*Chironomus plumosus, Tendipes semireductus, Polypedilum* sp., *Cricotopus* sp., *Procladius* sp.), Plecoptera (*Amphinemura* *standfussi, Capnia bifrons, Leuctra fusca, L. nigra, Nemoura cambica, N. cinerea, Perla marginata, Protonemura intricata*), bivalves (*Unio pictorum, Anodonta piscinalis, Sphaerium lacustre, Dreissena polymorpha*), Hirudinea (*Piscicola geometra, Hirudo medicinalis*), Ephemeroptera (*Palingenia* sp.), odonatele (*Gomphus pulchellus*), beetles (*Hydrophilus* sp.), Trichoptera (*Hydropsyche ornatula, Setodes* sp.), Gammarida (*Pontogammarus crasus, Dicherogammarus vilosus*). A major role of the biological production from the lacustrine ecosystems in the study area is represented by the populations of gastropods, preponderantly the benthic organisms that corresponds actively to the heterogeneity of the microhabitats they inhabit. There was identified 37 species, among which *Viviparus acerosus*, *Radix balthica*, *Physella* (*Costatella*) *acuta*, *Lymnaea stagnalis*, *Planorbarius coneus* are characteristic to the eutrophic lacustrine ecosystems in flood-prone areas (CIOBOIU 2014). It is noted that the largest number of species populates the muddy-detritus (24 species) bottom, near the shore, in shallow waters. These areas present the best possible feeding conditions. Gastropods find abundant food on the coarse detritus, on the leaves fallen in the water but still unaffected by putrefaction on which a rich periphyton is developeds and on the silt rich in organic substances. The smallest diversity of species was determined in the areas where the substrate is predominantly sandy (10 species) (**Tab. 1**). As it regards presence of bivalent heavy metals in sediments and shell of fresh water snails, it was found that there accumulated levels of Mn^{2+}, Fe^{2+} and Cu^{2+} are higher than the environment admissible values (0.001 – 0.01 mgl^{-1}), in accordance with accepted limits of international standards. The obtained results showed up the ability of snail species such as *Lymnaea stagnalis* to accumulate the metal ions of the type Mn^{2+}, Fe^{2+} and Cu^{2+} depending on the concentrations of the respective ions from the soil (**Tab. 2**). Also, the performed experiments showed increased tolerance of different species, such as *Radix balthica* and *Viviparus acerosus*, to the presence of bivalent metal ions originating from activities of industrial waste processing.

In this context, the above mentioned data are consisted with the development of such biotechnological processes based mainly on the activity of microorganisms, which demonstrates the effectiveness of bioremediation polluted environment with solid waste and toxic substances. Also, the reduction of SO_2 from coal can have many applications in fields such as: environmental protection in former mining perimeters and coal processing plants, as well in adjacent areas through the bioremediation of environments contaminated with sulfates and metal ions, in agriculture, food industry, chemical and pharmaceutical industries (WANG and CHEN 2009, LU et al. 2010, CISMAȘIU 2015, TOMUȘ et al. 2015).

The obtained results showed the increasing efficiency of the process of degradation of organic substances under the action of heterotrophic bacteria belonging to the *Acidiphilium* genus in the presence of salts existing in industrial contaminated sites in Romania (**Fig. 1, Fig. 2** and **Fig. 3**).

DISCUSSIONS

An important component of the investigated lacustrine ecosystems is represented by indigenous microorganisms. Performed studies showed that microorganisms from extreme environments have increased resistance to metallic ions present in them, having a greater capacity to reduce and oxidize the organic and inorganic compounds from the industrial habitats. This type of the extracellular metabolic adaptation could be used in the bioremediation processes of the contaminating industrial sites from Romania (JOHNSON and HALLBERG 2008, SINGH et al. 2011).

CONCLUSIONS

Taking into account the present state of the Danube River within the territory of Romania, state induced by diking, and the disappearance of the largest part of its natural floodplain, ecosystems studied represent an *area* that still preserves the specific biocoenotic structures. The presented data revealed the ecosystems biodiversity evolution subjected to the process of the eutrophication. The obtained results showed significant differences in the concentrations of heavy metals in water, sediments and the mass meat of invertebrate species living in chemically contaminated sites. The experiments suggest that the efficiency of the bioaccumulation process is strongly influenced by the type of metal ion, as well as their concentration in the water and sediments. Our study illustrates the toxic effects of metal ions on living organisms and especially biotechnology processes effectiveness in the reduction of concentrations of heavy metals in the wastewater by classical and modern systems to deal with them.

Species	**Benthal facies**		
	Sandy	**Muddy**	**Detritus**
Theodoxus danubialis	+	+	
Theodoxus fluviatilis	+		
Theodoxus transversalis	+		
Viviparus acerosus		+	+
Viviparus viviparus	+	+	
Valvata cristata		+	
Valvata (Cincina) piscinalis		+	+
Borysthenia naticina			+
Lithoglyphus naticoides		+	+
Bithynia tentaculata		+	
Bithynia (Codiella) leachii			+
Esperiana esperi	+	+	
Esperiana (Microcolpia) daudebardii		+	+
Esperiana (Microcolpia) daudebardii acicularis	+	+	+
Physa fontinalis			+
Physella (Costatella) acuta		+	+
Aplexa hypnorum			+
Lymnaea stagnalis		+	+
Stagnicola palustris	+	+	
Stagnicola corvus			+
Radix auricularia		+	+
Radix ampla		+	+
Radix balthica	+		+
Galba truncatula	+	+	
Ancylus fluviatilis	+		
Acroloxus lacustris		+	
Planorbis planorbis		+	+
Anisus (A.) septemgyratus			+
Anisus (A.) spirorbis		+	
Anisus (A.) vortex		+	+
Bathyomphalus contortus			+
Gyraulus albus		+	
Armiger crista			+
Segmentina nitida			+
Hippeutes complanatus		+	+
Planorbarius corneus		+	+
Oxiloma elegans		+	+

Tab. 1 Taxonomic composition according to the benthal facies

No. crt.	The analyzed indicator (mg/Kg/SU)	Sediments (mg/Kg/SU)	Shells (mg/Kg/SU)	The analysis method	The used apparatus
1	Iron	0.27	180	The working method specified in the user manual of the spectro-meter by the atomic absorption –Avanta GBS	The spectrometer of the atomic absorption with flame Avanta GBC, SN A 5378
2	Manganese	0.008	187		
3	Nickel	< SLD	0.475		
4	Chromium	< SLD	4.07		
5	Copper	< SLD	8.1		
6	Zinc	0.006	0.115		
7	Cadmium	0.0015	0.1		
8	Lead	< SLD	0		

Note: SLD – below the limit of detection

Tab. 2 Concentrations of metals from soil and shells of pulmonic snails *Lymnaea stagnalis*.

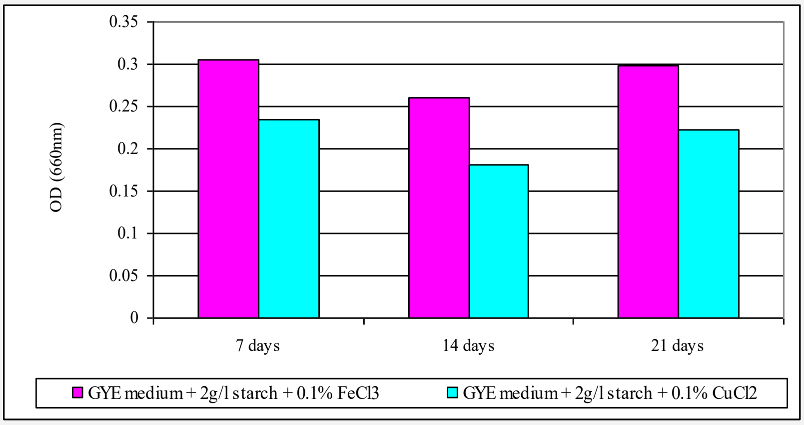

Fig. 1 The bacterial density of the *Acidiphilium* P_7 population in GYE medium with 0.1% $FeCl_3$, respectively 0.1% $CuCl_2$, and $2gl^{-1}$ starch.

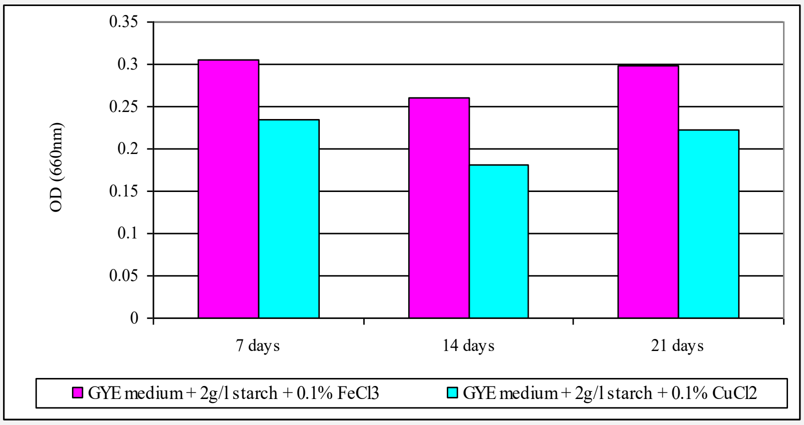

Fig. 2 The bacterial density of the *Acidi-philium* P_7 population in GYE medium with 0.1 % $FeCl_3$, respectively 0.1 % $CuCl_2$, and $2gl^{-1}$ starch.

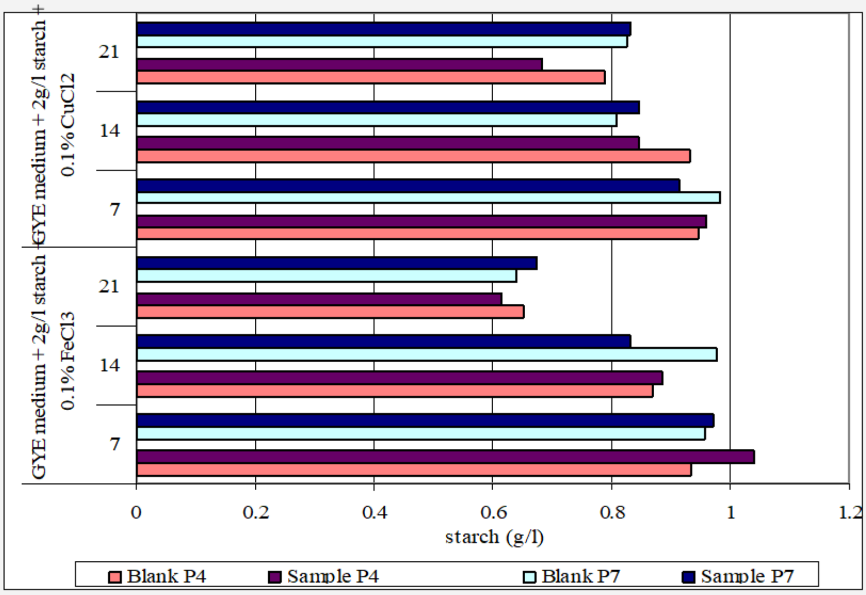

Fig. 3 The starch degradation of the extracellular enzymatic activity of *Acidiphilium* populations in GYE medium with 0.1 % $FeCl_3$, respectively 0.1 % $CuCl_2$, and $2gl^{-1}$ starch.

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