Reduced nitrogen loading enhances cyanobacterial blooms in Lake Peipsi

T. Nõges and I. Tõnno
Institute of Zoology and Botany, Estonian Agricultural University, Rannu, Tartumaa, Estonia
Institute of Zoology and Hydrobiology, University of Tartu, Tartu, Estonia
I. Blinova and E. Loigu
Tallinn Technical University, Department of Environmental Engineering, Tallinn, Estonia
V. Jastremski
Pskov Department of State Lake and River Fishery Research Institute, Pskov, Russian Federation
R. Laugaste
Institute of Zoology and Botany, Estonian Agricultural University, Rannu, Tartumaa, Estonia
B. Skakalski
Russian Hydrometeorological University, St.-Petersburg, Russian Federation

Lake Peipsi is one of the most important lakes of Europe having the fourth largest surface area after Lake Ladoga, Lake Onega and Lake Vänern. Being located on the border of Estonia and the Russian Federation, it is a transboundary water body and Europe's largest international lake. Lake Peipsi consists of three parts. The area of the largest northern part, Lake Peipsi *sensu stricto* (also Lake Peipus in the older literature, Chudskoe ozero in Russian), is 2,611 km^2, its mean depth is 8.4 m and its greatest depth 12.9 m. The southern part, Lake Pihkva (Lake Pskov, Pskovskoe ozero in Russian), with an area of 708 km^2 and a mean depth of 3.8 m, is connected with Lake Peipsi by the narrow river-shaped Lake Lämmijärv (Teploe ozero in Russian) having an area of 236 km^2 and a mean depth of 2.6 m. The catchment area (47,800 km^2) involves parts of Estonian, Russian and Latvian territories. The amount of water in Lake Peipsi is 25 km^3 and the residence time of the water is about 2 years (Jaani, 2001). The outflow, the River Narva, runs its waters into the Gulf of Finland. From 1918-1940 and from 1992 onwards, the lake has been divided between two different countries, which has hindered observations on the whole water body. The majority of phosphorous and nitrogen compounds are carried into the lake by the rivers Velikaya and Emajõgi. These two rivers altogether made up about 80% of the total loads of total nitrogen (TN) and 84% of total phosphorus (TP) to Lake Peipsi (Stalnacke, 2001). The River Velikaya is carrying biologically-treated waste water from the Russian town of Pskov (210,000 inhabitants), the River Emajõgi transports waste water from the Estonian town Tartu (120,000 inhabitants). The waste water of Tartu remained untreated for a long time; the treatment plant has been in operation since 1998. The contribution of the River Emajõgi to the main TN and TP loading of Lake Peipsi from Estonian territory is about 70% (Figure 1). The River Velikaya is contributing about 65% of all nutrient loading to Lake Peipsi (Stalnacke, 2001) and about 85% of that comes from the Russian territory.

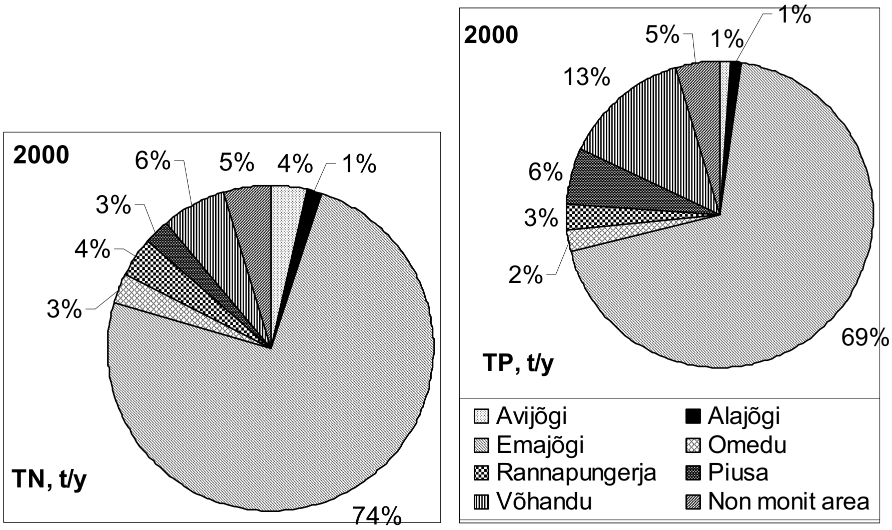

Figure 1. Contribution of different Estonian rivers to the total N and P loads to Lake Peipsi in 2000

The measurements of TP and TN in Lake Peipsi started in 1985 and in the Estonian rivers in 1984. In Russian rivers and waters of Lake Peipsi, mainly the mineral forms of nutrients (ammonium, nitrites, nitrates, phosphates) have been tested. The data series on mineral N and P compounds in Lake Peipsi start in 1968 and in the rivers in 1976.

From the 1980s to the beginning of the 1990s, the discharges of nutrients from the River Emajõgi increased drastically, while in the early 1990s a sharp decrease occurred, first of all in TN loading (Figure 2). This change was mainly caused by the collapse of Soviet-type agriculture where the fertilization of fields was heavy and often accompanied by a substantial leakage into the water bodies. As TN loading decreased more sharply than TP loading, the TN/TP ratio in the loading of the River Emajõgi and other Estonian rivers decreased (Figure 3).

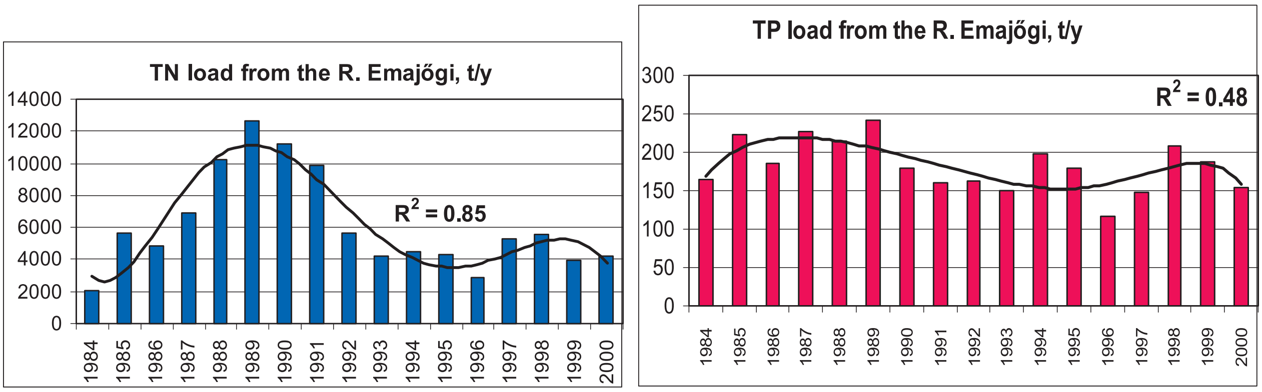

Figure 2. Long-term changes of total nitrogen (TN) and total phosphorus (TP) loading of the River Emajõgi

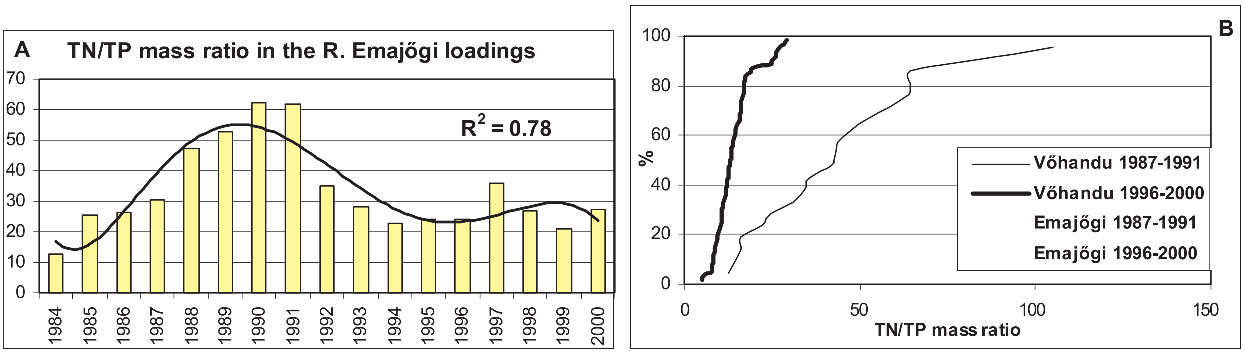

Figure 3. Long-term changes of TN/TP ratio in the River Emajõgi (A) and the cumulative distribution of N/P ratio in two main rivers in the Lake Peipsi watershed (B)

The decreasing tendency of the N/P ratio was also revealed in the River Velikaya, if one considers the ratio of measured mineral N and P concentrations (Figure 4).

The decreasing trend of the TN/TP ratio is also evident in lake water (Figure 5), though the changes have not been so sharp. The release of P from phosphorus-rich bottom sediments most probably buffer the decrease of the N/P ratio in lake water.

Further we examined, how a changed N/P ratio has influenced the composition of phytoplankton in Lake Peipsi. Cyanobacteria tend to dominate in lakes were the TN/TP mass ratio is low, mainly because of the ability of some species to use molecular nitrogen, the supply of which from the atmosphere is practically inexhaustible. Both N-fixing and non N-fixing cyanobacteria tend to dominate, if the TN/TP mass ratio decreases to 5-10 (Bulgakov and Levich, 1999; Michard et al., 1996; Seip, 1994; Schindler, 1977), some other authors regard the critical value to be even as high as 29 (Smith, 1983). In shallow lakes, cyanobacteria appear to be also more efficient than other phytoplankton species to convert phosphorus into their biomass (Nixdorf and Deneke, 1997). To examine changes of in-lake concentrations of nutrients and phytoplankton composition, we observed the values in July and August, as these are the most favourable months for the development of cyanobacteria. For 1983-2001, the average share of the biomass of N-fixing cyanobacteria (*Aphanizomenon* + *Anabaena* + *Gloeotrichia*) in July and August has increased in Lake Peipsi together with the decreasing TN/TP ratio. It is also evident that the dominance of cyanobacteria substantially enhances when the TN/TP mass ratio drops below 30 (Figure 5).

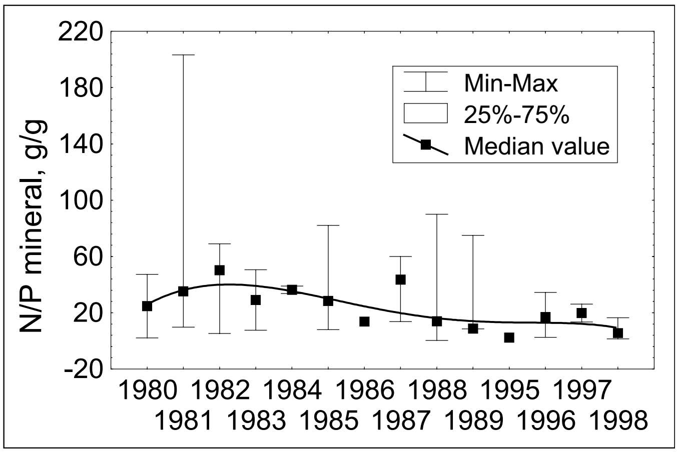

Figure 4. The ratio of mineral N and P in the River Velikaya in 1980-1998.

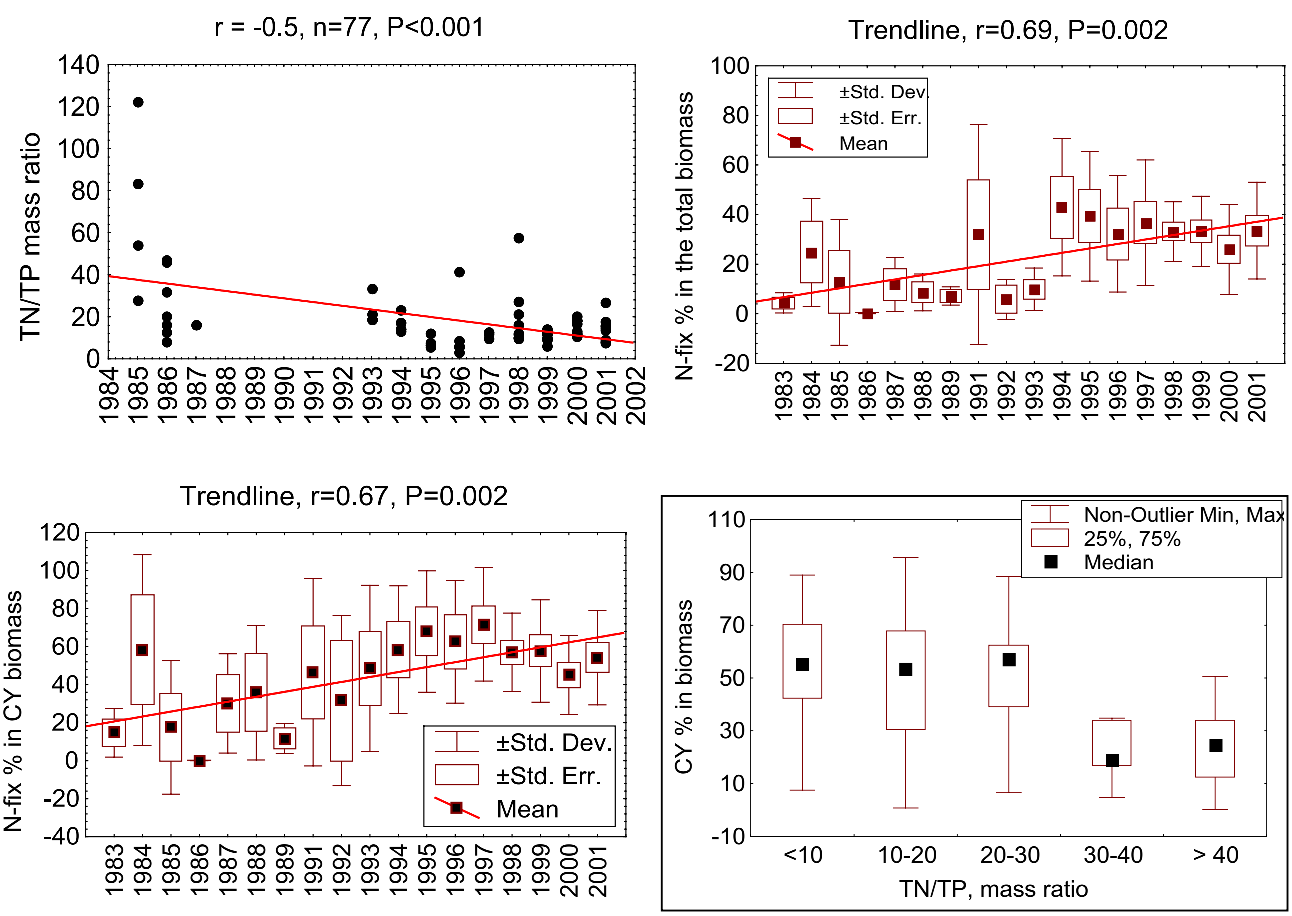

Figure 5. TN/TP mass ratio and the share of all cyanobacteria (CY) and N-fixing forms (*Aphanizomenon*+*Anabaena*+*Gloeotrichia*) in the phytoplankton biomass and in the biomass of cyanobacteria in July and August in Lake Peipsi (5 stations in Estonian waters)

Observing the changes in cyanobacterial dominance from the beginning of 1962s, one can notice an increase in the late 1960s and 1970s, a decline in the 1980s and a new increase in the 1990s (Figure 6). Cyanobacterial blooms are mainly attributed to declining water quality. In the case of Lake Peipsi, it is evident that cyanobacteria constituted about 50% of summer phytoplankton biomass already 40 years ago (Figure 6) and the cyanobacterial blooms have been documented since the 19th century (Laugaste et al., 2001). They almost disappeared in the conditions of extremely heavy nitrogen loading in the 1980s and it is possible that reduced nitrogen loading is driving the ecosystem closer to the natural conditions. Thus, water blooms may not always indicate a declining water quality. The same was also noticed in the case of the second largest, and also non-stratified lake of Estonia, Lake Võrtsjärv, where the bloom-causing cyanoprocaryotes (e.g. *Anabaena*) were already present at the beginning of the 20th century (Mühlen and Schneider, 1920).

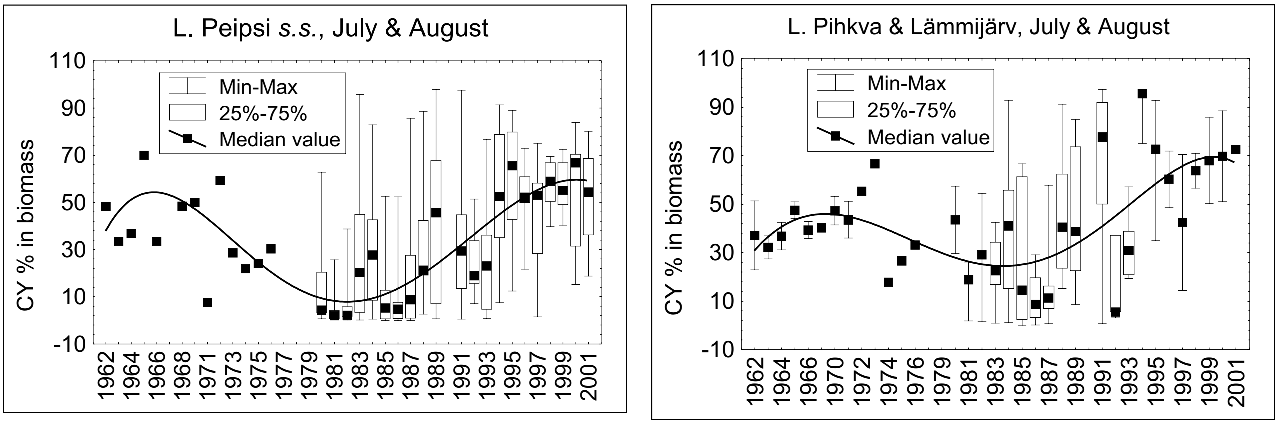

Figure 6. Long-term changes of the percentage of cyanobacteria (CY) in phytoplankton biomass in Lake Peipsi s.s. and Lake Pihkva.

Before estimating the present status of Lake Peipsi according to the Water Framework Directive, more studies should be made regarding paleolimnology and modelling to estimate the “pristine status” of this very large, shallow lake.

Acknowledgements

Funding for this research was provided by the Estonian Science Foundation grant 4080, and by the European Union projects ECOFRAME (contract EVK1-CT-1999-39) and MANTRA-East (contract EVK1-CT-2000-00076). The data obtained in the framework of the programme of environmental monitoring were used.

References

1. Bulgakov, N. G., and Levich, A. P., 1999. The nitrogen/phosphorus ratio as a factor regulating phytoplankton community structure, Arch. Hydrobiol., 146, pp. 3-22.
2. Jaani, A., 2001. Hydrological regime and water balance. Hydrological studies of Lake Peipsi: a historical review In: Nõges, T. (Ed.): Lake Peipsi. Meteorology, Hydrology, Hydrochemistry. pp. 38-40.
3. Laugaste, R., Nõges, T., Nõges., P., Jastremskij, V. V., Milius, A. and Ott, I., 2001. Algae. In: Pihu and Haberman (Eds.): Lake Peipsi – Flora and Fauna. Tartu, pp. 31-49.
4. Michard, M., Aleya, L., and Verneaux, J., 1996. Mass occurrence of the cyanobacteria *Microcystis aeruginosa* in the hypereutrophic Villerest Reservoir (Roanne, France): Usefulness of the biyearly examination of N/P (nitrogen/phosphorus) and P/C (protein/carbohydrate) couplings. Arch. Hydrobiol., 135, pp. 337-359.
5. Mühlen, M. von zur and Schneider, G., 1920. Der See Wirzjerw in Livland. Archiv für die Naturkunde des Ostbaltikums, 14, pp. 1-156.
6. Nixdorf, B. and Deneke, R., 1997. Why “very shallow” lakes are more successful opposing reduced nutrient loads, Hydrobiologia, 342/343, pp. 269-284.
7. Schindler, D. W., 1977. Evolution of phosphorus limitation in lakes. Science, 195, pp. 260-262.
8. Seip, K. L., 1994. Phosphorus and nitrogen limitation of algal biomass across trophic gradients. Aquatic Sciences, 56, pp. 16-28.
9. Stålnacke, P. (ed.), 2001. Nutrient Loads to Lake Peipsi. Environmental Monitoring of Lake Peipsi / Chudskoe 1998-99. Subproject Report Phase 2. Jordforsk Report No. 4/01, 65 pp.

Review of water quality in some areas of the littoral region of Lake Ohrid

Vera Novevska, Trajce Naumoski
Hydrobiological Institute, 6000 Ohrid, the former Yugoslav Republic of Macedonia

Water as an environmental factor is a basis for biota. It has a dual function: it is a physical factor (a medium in which numerous organisms partially or all their life live), and it is a “hydrogen donor” and transporter of the inorganic and organic matter (Ruttner, 1972).

In the water (as a biotope), a number of ecological factors act to which the organisms have adapted themselves. The specific character of this environment enabled the development of the plankton community that exclusively depends on the water environment (Ruttner, 1972).

Bacterial degradation and transformation of dissolved and detritus particles’ fractions play a key role in the cycle of inorganic and organic matter (Chrost, 1990). Factors or mechanisms that regulate the bacterial abundance are of crucial interest for aquatic ecology, because bacterial abundance is an essential parameter for the determination of the functional significance (Gurung et al., 2001).

Materials and methods

In 1997, comprehensive water-quality investigations of the littoral region of Lake Ohrid were performed. Water samples, which were analysed for microbiological and chemical parameters were collected at monthly intervals from the littoral region at the inflow of the River Sateska and at the outflow of the River Crn Drim at the town of Struga.

For microbiological analyses (organotrophic bacteria and facultative oligotrophic bacteria), total phosphorus and dissolved biodegradable organic matter were investigated. Facultative oligotrophic bacteria were cultivated on 10% mesopepton agar (MPA) and saprophitic bacteria on 100% MPA. Incubation was performed at 22 °C during a seven-days period. Dissolved biodegradable organic matter was determined as $KMnO_4$-consumption and total phosphorus was analysed with the per-sulfate digestion method (Menzel and Corvin, 1965; Strikland and Parsons, 1972).

Results and discussion

Organotrophic bacteria play a main role in the nutrient cycle and transformation of the organic matter, including the energy flow. Measurements of the bacterial activity in natural waters are very important, as Chrost (1990) says, to understand the functioning of the whole ecosystem. By utilizing dissolved biodegradable organic matter, the microbial community represents a significant portion of the organic matter in the water column.

Results from the investigations of the distribution of the heterotrophic bacteria have shown that facultative oligotrophic bacteria (developed on 10% MPA) varied between 349 and 9,800 bac/ml in the water at the outflow from the lake (River Crn Drim) and 698 to 15,740 bac/ml in the water of the River Sateska (inflow in the Lake Ohrid). Contrary, the number of saprophitic bacteria (developed on 100% MPA) varied between 60 and 4,360 bac/ml at the outflow, and 284 to 4,320 bac/ml at the inflow. It is evident that the numbers of the facultative oligotrophic bacteria are higher at both sites (Figure 1 and Figure 2).

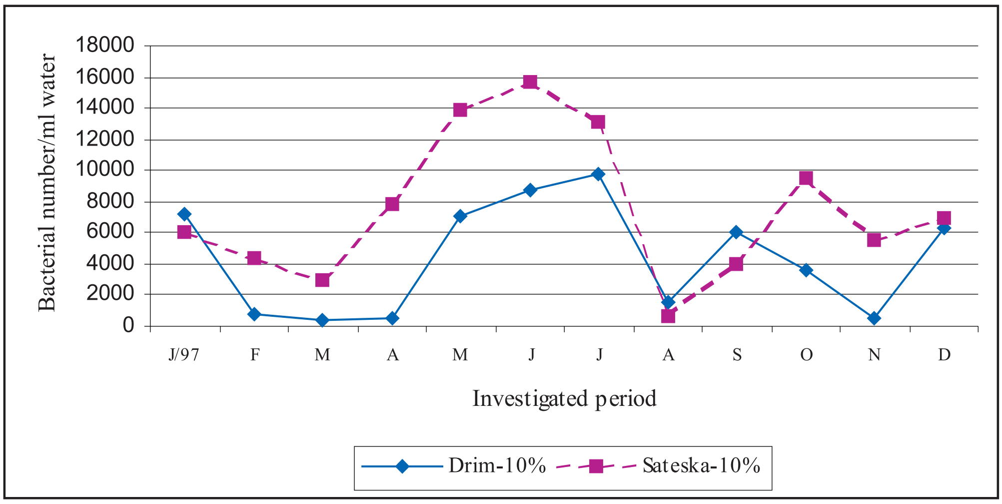

Figure 1. Number of facultative oligotrophic bacteria in the water at the investigated regions

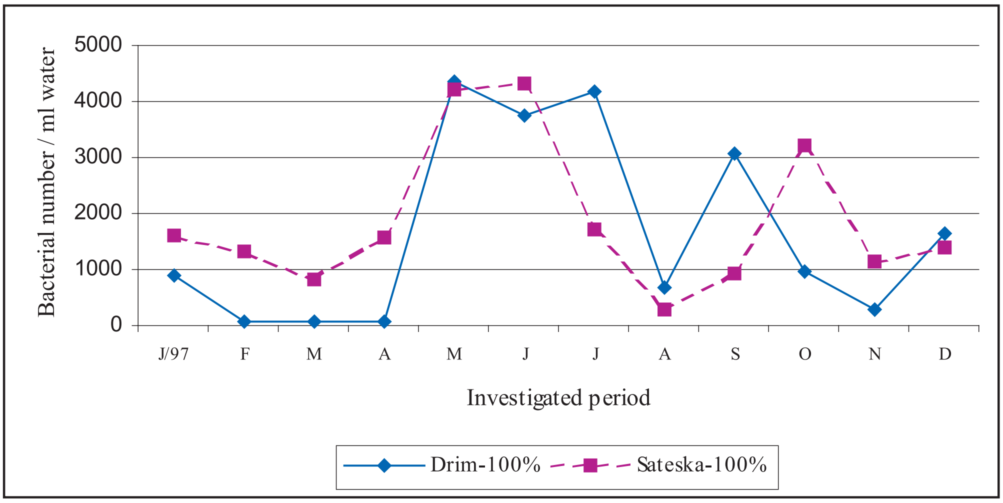

Figure 2. Number of saprophitic bacteria in the water at the investigated sites

Many investigations indicate that oligotrophic bacteria are the dominant microflora in the surface waters, representing about 50-90% of the total bacterial flora (Gajin et al, 1990). Investigations by Curcic and Comic, as shown by Milosevic (1999), in Lake Vlasina (artificial lake in Yugoslavia) revealed the following percentage: facultative oligotrophic bacteria – 69.46%, and heterotrophic bacteria – 30.54%.

At the meeting of the Subcommittee of the Japanese Society for Microbial Ecology (1980), oligotrophic organisms have been defined as organisms growing in environments where the organic carbon concentrations are below 1 mg C/l (Ishida and Kadota, 1981).

Speaking in terms of seasonal distribution of these bacteria, their number was at maximum during the summer period when the temperature was high. This condition allowed intensified mineralization of the organic matter and the bacterial activity reached high values (Figure 3).

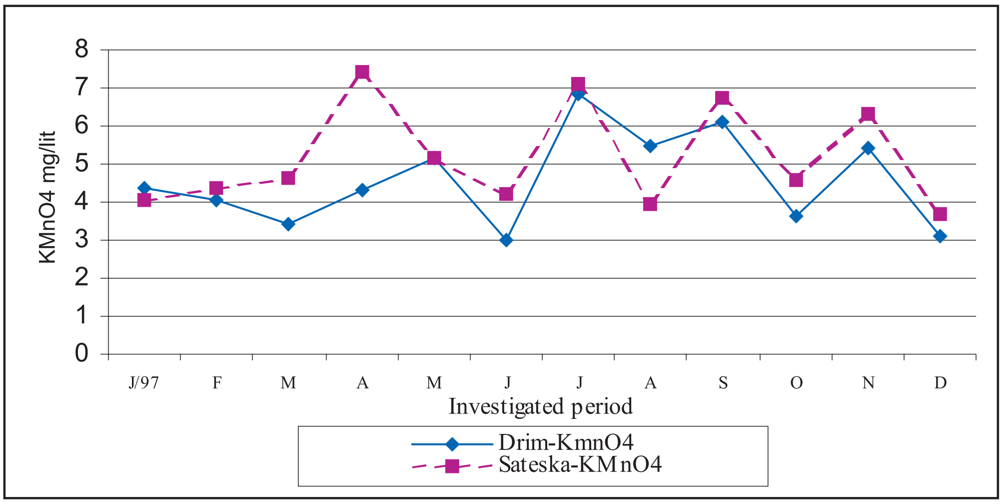

Figure 3. Content of dissolved organic matter in the water at the investigated sites

Littoral regions, compared to the pelagial region, are characterized by higher productivity. Actually, the littoral region is characterized by higher input of alochtonous organic matter and the autochtonous primary productivity is mainly done by the macrophytic vegetation, phriphyton and the phytoplankton. Because of the relatively high values of the allochtonous and autochtonous dissolved biodegradable organic matter in the littoral zone, there is a strong relation between autotrophic and heterotrophic communities that have a significant influence at the whole lake metabolism (Chrost and Overbeck, 1990).

During the investigated period, the content of the dissolved biodegradable organic matter varied between 3.02 and 6.82 mg/l in the water of the outflow (River Crn Drim), and from 3.69 to 7.44 mg/l in the littoral region at the inflow (River Sateska).

The present dissolved biodegradable organic matter (either of autochtonous or allochtonous origin), is part of the complex methabolism that continuously act in the lake water (Naumoski, 2000).

Phosphorus is an element that is often the limiting factor of the primary productivity in aquatic ecosystems. The total phosphorus content varied during the investigated period between 0.04 and 0.82 µM/l in the outflow water (River Crn Drim), and 0.11 to 1.03 µM/l in the littoral region at the inflow of River Sateska (Figure 4).

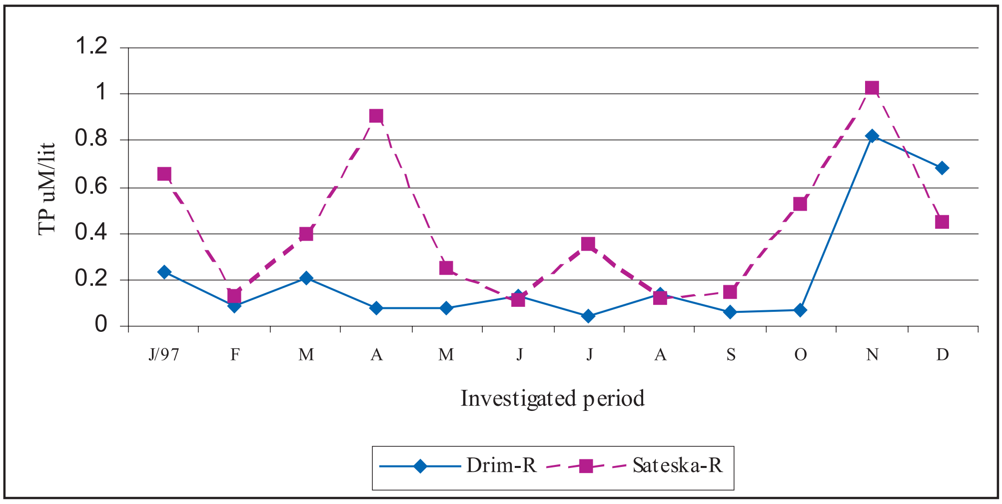

Figure 4. Content of total phosphorus in water at the investigated sites

Having in mind that the rivers represent "best" recipients of any kind and nature of waste, their loading has a direct impact on the littoral region and the nutrient loading of the lake. This conclusion is also supported by other parameters that show increased values in the area where the River Sateska flows into Lake Ohrid.

According to Naumoski (2000), the River Sateska contributes to the total phosphorus loading of Lake Ohrid with 39% (3.81 t/year) and to the outflow water with 16% (2.92 t/year).

Conclusions

The results from the investigation period 1997 indicate that the facultative oligotrophic bacteria were dominant at both sites of the littoral region of Lake Ohrid (area at the inflow of River Sateska and area at outflow of River Crn Drim). Both groups of bacteria (facultative oligotrophic and saprophitic) show higher numbers during the spring period, especially at the inflow of River Sateska.

Dissolved biodegradable organic matter is variable during the investigated period with higher dominance at the inflow of River Sateska. The total phosphorus content varied between 0.04 and 0.82 μM/l in the outflow water (River Crn Drim) and 0.11 to 1.03 μM/l in the littoral region at the inflow of River Sateska. This parameter has higher values in the littoral region where the impact of inflow water is evident.

References

1. Chrost, R. J., 1990. Microbial ectoenzymes in aquatic environments. In: Overbeck J. and Chrost, R. J. (eds): Aquatic Microbial Ecology. Biochemical and Molecular Approaches. Springer Verlag. New York, pp. 47-78.
2. Chrost, R. J., Overbeck, J., 1990. Substrate-ectoenzyme interaction: Significance of β̃glucosidase activity for glucose metabolism by aquatic bacteria. Arch. Hydrobiol. Beih. Ergeb. Limnol. 34, pp. 93-98.
3. Gajin, S., Gantar, M., Bokorov, M., Matavuli, M., Petrovic, O., Obreht, Z., Radnovic, D., 1990. Oligotrophic microflora of surface waters. 2nd Yugoslav Symposium of Microbial Ecology. Proceedings. Zagreb (in Serbian).
4. Goldman, C. R., 1983. Limnology. McGraw-Hill Book Company, New York.
5. Gurung, T. B., Kagami, M., Yoshida, T., Urabe, J., 2001. Relative importance of biotic and abiotic factors affecting bacterial abundance in Lake Biwa. Limnology. 2, pp. 19-28.
6. Ishida, Y., Kadota, H., 1981. Growth patterns and substrate requirements of naturally occurring obligate oligotrophs. Microb. Ecol. 7, pp. 123-130.
7. Menzel, D., Corwin, N., 1965. The measurement of total phosphorus in seawater based on the liberation of organically bound fractions by persulfate oxidation. Limnol. Oceanogr. 10, pp. 280-282.
8. Milosevic, M. S., 1999. Dynamics of microbial community in Lake Grocka. Master thesis. Faculty of Natural Sciences. University of Kragujevac. 115 pp. (In Serbian with English summary).
9. Naumoski, T. B., 2000. Phosphorus loading of Lake Ohrid. PhD thesis. Faculty of Natural Sciences, Skopje. 173 pp. (In Macedonian with English summary).
10. Ruttner, F., 1972. Fundamentals of limnology. University of Toronto. Press Toronto Buffalo. 307 pp.
11. Strikland, J. D. H., Parsons, T. R., 1972. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Canada. 167 pp.

Mercury in bottom sediments of port basins and canals in the Oder estuary

Mikołaj Protasowicki
Department of Toxicology, Agricultural University of Szczecin
Edward Niedźwiecki
Department of Soil Science, Agricultural University of Szczecin

Introduction

Port waters of the Oder estuary, similarly to other parts of the world, are especially exposed to contamination due to ship traffic, trans-shipment, discharge of municipal and industrial wastes, precipitation run-off and pollutants from other sources. Pollution is clearly evident in port basins and canals where water exchange is considerably smaller than in the river current.

One group of pollutants are heavy metals. These elements have always been found in the environment and certain amounts of them are essential for proper functioning of plant and animal organisms but their excessive content may be harmful. Intensifying human economic activity distributed their natural cycle and as a result in many regions of the world geochemical content of trace elements is exceeded.

Sedimentation processes are of vital importance for the circulation of metals in the environment. Due to sorption capacity, the suspended matter of surface water binds these elements, which leads to their deposition in bottom sediments from where they may be released in considerably limited amounts (Salomons and Förstner, 1984). Secondary release is possible during dredging, transportation and deposition of dredged material on special dumping grounds.

Mercury, like cadmium and lead, is considered to be unambiguously toxic with only a negative effect on organisms. It was known in ancient times and its compounds were used for therapeutic purposes till our times. In 1914, fungicides containing mercury were introduced and applied in agriculture until the 1970s. Mercury was also used in industry. As a result there was local contamination of certain ecosystems.

Turekian and Wedephol (1961) and Förstner and Müller (1974) state that geochemical content of mercury in river bottom sediments does not exceed 0.400 $\mu g \cdot g^{-1}$ dry matter. Similar opinion may be found in other authors' publications. In our earlier papers it was proved that in deeper layers of Zalew Szczeciński (Szczecinski Lagoon) sediments the values were often below 0.100 $\mu gHg \cdot g^{-1}$ dry matter and there was a positive correlation between mercury content and the content of other metals and the level of organic matter (Protasowicki et al., 1993).

The aim of this study was to determine the degree of contamination of bottom sediments extracted during dredging port canals and basins located in the Oder estuary.

Materials and methods

Bottom sediments collected during dredging port canals and basins in the years 1995-2001 were examined. Totally 187 samples were taken from the following places: Szczecin – 71 samples, Police – 8, Świnoujście – 77, Nowe Warpno – 26, Dziwnów – 3 and Wolin – 2.

The sediments were sifted through a polyethylene sieve with openings of 2 mm in diameter.

Mercury was determined by means of atomic absorption spectrometry using a cold vapour technique after digestion of sample in mixture of nitric and perchloric acids according to Adrian method (1971). Accuracy of method was tested on the basis of mercury determination in reference material MESS-2, and at the same time precision of method was determined.

Organic matter content was estimated by losses on ignition at the temperature of 550 °C.

Results and discussion

As a result of 5 parallel analyses of the reference material MESS-2 (sea sediments) 0.091 ± 0.004 $\mu gHg \cdot g^{-1}$ dry matter was determined in relation to the reference value of 0.094 ± 0.009 $\mu gHg \cdot g^{-1}$ dry matter. This result confirms that applied analytical method allows to obtain accurate and credible results. Precision of the method is very high, which is supported by a very small results variation (V = 4,40%) in analysis replications.

The sediments under study consisted of both sands and mud. The losses on ignition, ranging from 0.07 to 25.60% (8.73% on the average), show that there were considerable differences in their organic matter content. Generally, the sediments from Police and Szczecin were slimy with a considerable amount of organic matter whereas those from the remaining ports mostly sandy with a slight mud addition (Table 1), which determined the sediment mercury content. It was within range 0,000 to 3.706 $\mu gHg \cdot g^{-1}$ dry matter (0.646 $\mu g \cdot g^{-1}$ d.m. on the average). The analysis of the relationships between those parameters showed that they may be described by equation $y = 0.0839x$ and correlation coefficient $r = 0.820$.

According to decreasing content of mercury these bottom sediments may be ranked as follows: Szczecin > Police > Świnoujście = Nowe Warpno > Dziwnów > Wolin (Table 1). This supports our previously formulated conclusion that with the growing distance from Szczecin heavy metal content decreases (Protasowicki and Niedźwiecki, 1993). There were no great differences between the present results and those obtained before (Protasowicki and Niedźwiecki, 1993; Protasowicki et al., 1993, 1999).

Considering the results in the light of natural geochemical mercury content given by Turekian and Wedephol (1961) and Förstner and Müller (1974) it should be stated that about 60% of sediments are not contaminated. In the light of boundary heavy metal content in the surface layer of soil contaminated to a different extent, according to the recommendation of The Institute of Fertilisation and Soil Science (Kabata-Pendias et al., 1993) and Polish soil standards (Mon. Polski, 1986; Dz.U., 1999) the concentration of mercury exceeded these values only in about 10% of the sediments under study. However, it should be mentioned that even the highest recorded values are much lower than the permissible values for sewage sludge for soil application (Dz.U., 1999). There were several times lower than those given by Förstner and Müller (1974) and Herms and Tent (1982) in the case of river estuaries in Germany, and even two orders of magnitude lower than mercury concentration found in river sediments in considerably polluted regions, e.g. near goldmines or plastic works where the value was 150, and even 240 $\mu gHg \cdot g^{-1}$ dry matter (Cocking et al., 1991; Malm et al., 1990).

Recently, Ministry of the Environment has presented a project according to which concentration of mercury in uncontaminated dredged material should not exceed 1 $\mu g \cdot g^{-1}$ dry matter. Higher value was found in the case of 27,30% of analysed sediments samples. The project does not differentiate dredged materials as regards their qualities, which would allow taking into consideration a highly significant correlation between mercury concentration in sediments and the content of organic matter estimated on the basis of losses on ignition. Therefore, it seems that in estimating the degree of contamination, the content of mercury should be standardized in relation to the sediments with a definite amount of organic matter. Such a procedure is used in the Netherlands where the standard sediment has 10% organic matter concentration (Rotterdam Maritime Group, 1996).

Conclusions

Mercury content in the sediments of the port canals and basins in the Oder estuary was not very high, although in some samples it exceeded permitted limits.

The highest content of this element was recorded in sediments dredged during deepening port basins and canals in Szczecin, and much lower content in the sediments from the areas near the sea.

There was a very high correlation between the mercury content and the organic matter amount in the sediments, which suggests the need for considering that parameter (data standardization) while estimating the degree of contamination with this metal.

Table 1. Mercury content and losses on ignition in bottom sediments of port basins and canals in the Oder estuary

Data	Total values	Szczecin	Police	Świnoujście	Nowe Warpno	Dziwnów	Wolin
Mercury content, μg·g^{-1} dry matter							
N	187	71	8	77	26	3	2
min - max	0.000 - 3.706	0.000 - 3.706	0.114 - 2.024	0.000 - 0.728	0.000 - 1.622	0.006 - 0.136	0.005 - 0.005
median	0.225	1.523	0.231	0.108	0.027	0.037	-
mean	0.646	1.346	0.471	0.189	0.231	0.060	-
standard dev.	0.821	0.902	0.687	0.201	0.434	0.068	-
Losses on ignition, % dry matter							
N	187	71	8	77	26	3	2
min - max	0.07 - 25.60	0.19 - 25.60	0.11 - 19.60	0.07 - 16.10	0.07 - 23.60	1.30 - 7.00	0.54 - 0.57
median	6.57	16.00	10.11	3.29	2.20	2.37	-
mean	8.73	14.15	11.46	4.89	5.33	3.56	-
standard dev.	7.55	7.11	5.96	4.40	6.97	3.03	-

References

1. Adrian, W, 1971. A new digestion method for biological material utilizing pressure, At. Absorpt. Newsl., 10(4), 96.
2. Cocking, D., Hayes, R., Lou King, M., Rohrer, M.J., Thomas, R. and Ward, D., 1991. Compartmentalisation of mercury in biotic components of terrestrial flood plain ecosystem adjacent to the South River at Waynesboro, VA. Water, Air, Soil Pollut., pp. 57-58, 159-170.
3. Dziennik Ustaw, RP, 1999. Rozporządzenie Ministra Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa z dnia 11 sierpnia 1999 r. w sprawie warunków jakie muszą być spełnione przy wykorzystaniu osadów ściekowych na cele nieprzemysłowe. Nr 72, poz. 813, pp. 3889-3892.
4. Förstner, U. and Müller, G., 1974 Schwermetalle in Flussen und See als Ausdruck der Umweltschmutzung. Sprengier-Verlag, Berlin Heidelberg, New York.
5. Herms, U. and Tent, L., 1982. Schwermwtallgehalte in Hafenschlick sowie in landwirtschaflich genutzten Hafenschlamm-Spülfeldern im Raum Hamburg. Geol. Jb., F 12, pp. 3-11.
6. Kabata-Pendias, A., Motowicka-Terelak, T., Piotrowska, M., Terelak, H. and Witek, T., 1993. Ocena zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. Ramowe wytyczne dla rolnictwa. IUNG Puławy, Ser. P (53), 20s.
7. Malm, O., Pfeiffer, W., Souza, C. and Rether, R., 1990. Mercury pollution due to gold mining in the Madeira River Basin, Brazil. Ambio, 19(1), pp. 11-15.
8. Monitor Polski, 1986, 23, poz. 170, 285 pp.
9. Protasowicki, M.and Niedźwiecki, E., 1993. Zawartość metali ciężkich w osadach dennych portów ujścia Odry. Studia i Materiały MIR, seria S, pp. 117-120.
10. Protasowicki, M., Niedźwiecki, E. and Ciereszko, W., 1993. Heavy metals content and chlororganic substances in sediment cores from the Szczecinski Lagoon. In: Pollutants in Environment (eds. Smoczyńska A. et al.), ART Olsztyn, pp. 155-159.
11. Protasowicki M., Niedźwiecki, E., Ciereszko, W., Perkowska, A. and Meller, E., 1999. The comparison of sediment contamination in the area of estuary and the lower course of the Oder before and after the flood of summer 1997. Acta Hydrochim. Hydrobiol., 27(5),pp. 338-342
12. Rotterdam Maritime Group, 1996: Port Modernisation Study Poland. Szczecin-Świnoujście Maritime Region. Soil Investigation Report, vol. 2D, (prepared for The World Bank Washington by Rotterdam Maritime Group the Netherlands).
13. Salomons, W. and Förstner, U., 1984. Metals in the hydrocycle. Sprengier-Verlag, Berlin, 349 pp.
14. Turekian, K.K. and Wedephol, K.H., 1961: Distribution of the elements in some major units of the Eart's crust. Bull. Geol. Soc. America, 72, pp. 175-184.

Reconstruction of proper wetland management in the case of Czarnocin Basin

Kazimierz Rabski
European Union for Coastal Conservation (EUCC) – Poland

Among many interesting parts of the transboundary area in the catchment of the Szczecinski Lagoon, the eastern part of local rivers and channels (Czarnocin Basin) seams to be one of the most valuable. A rich biodiversity and interesting examples of sustainable use and nature protection could, in the nearest future, make the Czarnocin Basin even a model area. That is one of the major aims of the Polish activities of the European Union for Coastal Conservation.

From the geological point of view, the Szczecinski Lagoon and surrounding area, especially Czarnocin Basin, are very young. The actual shape of landscape and morphological units has been created after the bay has been disconnected from the open sea by coastal processes, around 5,000 years ago. From this period, several stages characteristic for landscape formation can be distinguished. For reconstruction of proper wetland management their recognition is quite important. The first stage can be defined as a period of intensive peat land development in many places covering former coastal dune areas. In many other places, this kind of deposition has formed new lands on shallow waters of the lagoon. The second stage was dominated by formation of woodland with still significant influence of open swamps. This kind of landscape has dominated in the area approximately till the 16th century. This can be seen as the beginning of human impact on the landscape, which became especially intensive after the beginning of the 19th century. Development of farming and shipping has reduced natural processes. The second part of the 20th century has brought new challenges for economic development, but, at the same time, increased threat to nature values. Massive wetlands drainage for intensive agriculture development, as was characteristic for the “kolkhoz” systems in this region, has changed natural relations in this sensitive ecosystem.

Even this very simplified chronology gives a good background to the most important question: what can be identified as proper wetland management?

The European Union for Coastal Conservation – Poland, after having recognised existing and potential values of the Czarnocin Basin, has started to realise a multidisciplinary programme where the most important aims are:

- To purchase (or lease) the most valuable parts of coastal meadows and wetlands;
- To prepare a management plan for owned area and management suggestions for surrounding terrains;
- To reconstruct changes in wetland landscape and land use for at least last one hundred years;
- To make an inventory of existing flora and fauna in the light of the observed changes;
- To implement possible forms of human activities with special attention to active nature conservation and sustainable development of local communities;
- To provide ecological education;
- To establish a model of sustainability in the context of the Szczecinski Lagoon.

At the moment, thanks to support from the Dutch Government (via the ECONET Action Fund) and to the projects realised together with EUCC-The Coastal Union and the Dutch Society “Natuurmonumenten”, EUCC-Poland has been able to purchase or lease about 500 ha of Czarnocin Basin and prepare a management vision for this area. This document is taking into consideration some management measures, which will be necessary for reconstruction of proper wetland management.

There are some groups of measures established as follow:

- Hydrology
  - Inventory of existing surface water circulation and possibilities to improve the system of canals / channels;
  - Projecting and negotiating changes in drainage system to keep water on a higher level in the selected areas;
  - Preparing selected areas for permanent and occasional flooding;
  - Cleaning channels / canals and reduce their overgrow;
  - Monitoring water level and circulation to keep conditions characteristic for wetlands;

- Vegetation management by mowing
  - Twice a year mowing of selected areas of grassland;
  - Reduce overgrow of canals / channels by mowing *Phragmites* and *Carex;*
  - Reduce reeds succession on open wetland areas;
  - Periodical mowing for reduction of young trees and some bushes;
- Vegetation management by grazing
  - Implementation of meat cattle with density of flock up to 150, with preferable *Scottish Highland* and *Lemusine;*
  - Fencing and establishing system of grazing quarters;
- Realising selected aspects of education and tourism
  - Preparation of education trails;
  - Building bird-watch towers;
  - Providing education trainings;
  - Establishing visiting centre;
  - Publishing.

Parallel to the development of management plans, some preliminary activities have been started. One of them is a study aimed at the reconstruction of wetlands changes and land use for the last hundred years as well as an inventory of surface water and their circulation in the system of existing channels. Inventories of flora and fauna are also under preparation. For example, more then 12 protected species of birds were observed.

At the same time, to implement extensive agriculture as a method of active nature conservation, some experiments have started with grazing. Actually about 80 Lemusine cows and 10 Konik Polski graze the terrains of EUCC-Poland.

Reconstruction of proper wetland management cannot be realised without the local context. The local community of village Czarnocin must take actively part in the long-term process. That is why, where possible, local people are part-time employed and an education programme is focused on this group of public.

Such a programme is also a chance for other forms of development, as tourism. Actually in the Czarnocin Basin some facilities for tourism were realised. Thanks to support from EcoFund Foundation, two bird-watch towers have been built, an education trail was realised and some information materials have been published.

The activities connected with reconstruction of proper wetland management in Czarnocin Basin started in 1998, so it is not yet possible to draw conclusions on the work done. However some positive aspects are observed at the following levels:

- Nature conservation (inventory, establishing methods of conservation, grazing, mowing, education);
- Local sustainable development (re-organizing agriculture in a sustainable way, development of eco-tourism).

Works should continue to establish in 2005 a model area of a sustainable Czarnocin Basin.

Water quality problems in Baltic coastal waters: the Oder River as a source of human pathogenic viruses

Gerald Schernewski and Iwan Tejakusuma
Baltic Sea Research Institute Warnemünde (Institut für Ostseeforschung Warnemünde)
Timo Huttula
University of Helsinki, Finland
Wolf-Dieter Jülich
Institute of Pharmacy, University of Greifswald, Germany
Victor Podsechin
Pirkanmaa Regional Environment Centre, Tampere, Finland

Introduction

Summer tourism is the most important economic factor in the Oder estuary and further growth is expected. For a sustainable development of bathing tourism, a high quality of water is imperative. The Oder River drains about 17 km^3 water per year, as well as large amounts of nutrients and pollutants into the lagoon and further in the Baltic Sea. The result is eutrophication with intensive algal blooms. From a hygienic point of view and despite local problems, the bathing water quality in the Szczecinski Lagoon and along the Baltic Sea coast nowadays can be regarded as good or very good. This does not mean that hygienic water quality problems do not exist any more. Especially infective viruses, which are usually not measured in the bathing water quality programme, are a largely unknown potential hazard for water sports, swimming and bathing in the lagoon and along the outer Baltic coast.

Human pathogenic viruses can be expected in all waters that are affected by municipal waste water, but usually these virus concentrations in natural surface waters are low due to dilution and fast decay. Already a few viruses can cause the infection of predisposed persons. Therefore, even low virus concentrations can be a problem. Infections and subsequent swimming prohibitions can seriously affect the reputation, public acceptance and economic development of the resorts.

The city of Szczecin with a population of about 420,000 inhabitants is located on the Oder River, 21 km upstream of the Szczecinski Lagoon. At present, about 47.4 million m^3 of waste water accrue per year. 67% of all waste water is directly and without treatment, discharged into the Oder (Wallbaum and Rudolph, 2000; Boczar and Szaniawski, 1993). The city therefore has to be regarded as a major source for hygienic water quality problems of the coastal waters.

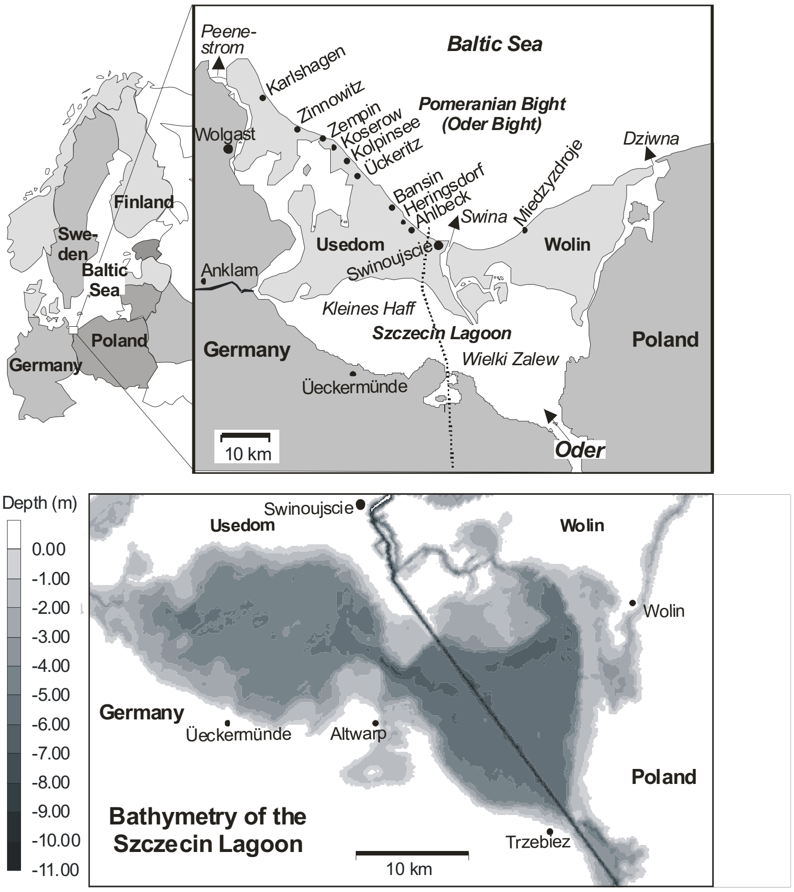

Figure1. Location of the Oder estuary, consisting of the Szczecinski Lagoon and the Pomeranian Bight The discharge by the Oder, as well as the outlets Peenestrom, Swina Strait and Dziwna, are indicated by arrows. Below: Bathymetric map of the shallow Szczecinski Lagoon at the German/Polish border

Methods

To analyse the hazard of virus infections along the shores and beaches of the Oder Lagoon, we linked laboratory measurements to a two-dimensional flow and transport simulation model and carried out scenario simulations. Here we present the example of 14 August 2001. Other, more detailed examples are presented in Schernewski and Jülich (2001). The Oder Lagoon is shallow (average depth of 3.8 m) and only some central areas show a temporary vertical stratification. It allowed the application of the two-dimensional, finite element, flow model FEMFLOW2D. The model is described in detail in Podsetchine and Schernewski (1999). The virus transport was calculated with a particle tracking module. The passive particles movement was simulated on the basis of the pre-calculated flow field. The decay of viruses was simulated by repetitive applications with logarithmic reduced particle numbers and increased simulation times. Transport simulations need reliable flow fields, which are in agreement with flow measurements. For 14 August 2001, detailed flow measurements from 3 independent sources were available and allowed the model validation. Several cross sections measurements with an Acoustic Doppler Current Profiler (ADCP), installed on a small boat, were carried out in the Small Lagoon. On several stations, the boat anchored and measured detailed vertical current profiles. In Figure 2 the depth-averaged current values for these 4 stations are given. Close to the shore, vertical current profiles with an inductive current-meter ISM 2000 were taken and the 2 stations with the largest distance to the shore are presented too (Figure 2). Close to the German/Polish border a fixed station by GKSS, Geestacht, measures current time series. This data is not shown but in good agreement with our simulated flow field.

In the scenario simulation based on this flow field, we assumed a virus concentration of 10^7/m³ waste water. This means that the waste water released into the Oder near Szczecin contained an enteric virus number (of varying virus composition) of 10^{11} to 10^{12} infective units. This is equal to about 100 infected persons (0.02% of the population of Szczecin), which usually excrete about 10^4 to 10^{10} viruses per g excrement.

The assumption holds for an average situation. In an epidemic, a much higher virus release can be expected (Schernewski and Jülich, 2001).

Altogether about 130 virus types are known to cause water-borne infections (Dumke and Feuerpfeil, 1997). For inactivation measurements in the laboratory, Polio-1 viruses were chosen, which are known to be very stable in natural waters. Polio-1 viruses entirely linked to suspended matter have a 90%-degradation time of 14 days (Schernewski and Jülich, 2001) and become inactivated after 57 days. Due to sedimentation, the suspended matter concentration from the Oder mouth into the Baltic Sea is reduced by 90%. The sedimentation loss in the lagoon was negligible compared to the decay rate and was not taken into consideration. The same is true for inactivation during river transport, which was not considered. Starting condition in the Oder mouth was a virus concentration of 10^4 viruses/m^3. It was assumed that 10 viruses are linked to one particle.

Results and discussion

The depth averaged simulated flow velocities are very well in agreement with ADCP as well as with conductive flow measurement. The same is true for the current direction. Due to the limited spatial resolution of the triangular flow calculation grid, slight deviations occur. In the simulation, a slightly inhomogeneous wind field, with some shelter due to shoreline vegetation, was applied. The simulated flow field can be regarded as reliable. The prevailing south-westerly wind conditions during on 14 August 2001 are typical, but the average wind speed was comparatively high for a sunny summer situation. The water temperatures were around 20°C and matched the laboratory conditions applied during the virus tests in river water very well.

Due to a short degradation time, free viruses affect only the Oder River mouth. The situation for the viruses completely linked to suspended matter is presented in Figure 2. Starting condition is a virus concentration of 10^4. This again is represented by 1000 particles with 10 viruses each. Figure 3 shows the spatial distribution and the decrease in number after 14 and 28 days. After 14 days, 100 particles are left. After 28 days, the number of remaining particles has decreased to 10. EU regulations for bathing water [1] are met, when 95% of all samples show no viruses in 10 litre water. As a rough estimation, it can be assumed that areas where no trajectories are shown are in compliance with the EU Directive. Despite that, single viruses can survive up to 56 days in the lagoon and enter the Small Lagoon as well as the Baltic Sea.

These results are in compliance with virus measurements. In 1997, a maximum of 10^2 infective units per m^3 was observed near Police (12 km north of Szczecin). Near the Haff buoy at the German/Polish border and the entrance to the Small Lagoon (Figure 1) an average of 10 infective units per m^3 was found once in 1997 and during 1998 and 1999 no viruses were observed. The applied standard method detects the number of free viruses in 10-litre sample water. The values for 1997 were averaged and converted into viruses/m^3.

One has to be aware that the results presented in Figure 2 are a simplification and contain several uncertainties. All viruses are assumed to be attached to suspended matter and all types of viruses are expected to behave like the Polio-viruses in the laboratory experiment. The uncertainties linked to the virus experiments are a magnitude larger than the one arising from flow and transport simulations. One has to keep in mind that the simulations yield depth-averaged flow velocities single water sheets can show significant higher or even opposite current velocities. The transport was calculated on the basis of T_{90}-values at 20 °C. At colder temperatures viruses survive a longer time and the scenarios would be worse at lower temperatures. High virus concentrations are a hazard only during summer, when a lot of water activities take place. Therefore the practical implication of lower water temperatures, which are characteristic for other seasons, is negligible. It is still unknown to what extent viruses can and will be attached to clay in natural surface water, to what extent they survive sedimentation and resuspension processes and remain infective. Linked to clay, viruses generally can be transported far into the Small Lagoon and more detailed studies are necessary to evaluate their behaviour and hazard.

[1] Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water, published in the Official Journal L 031 of 05/02/1976.

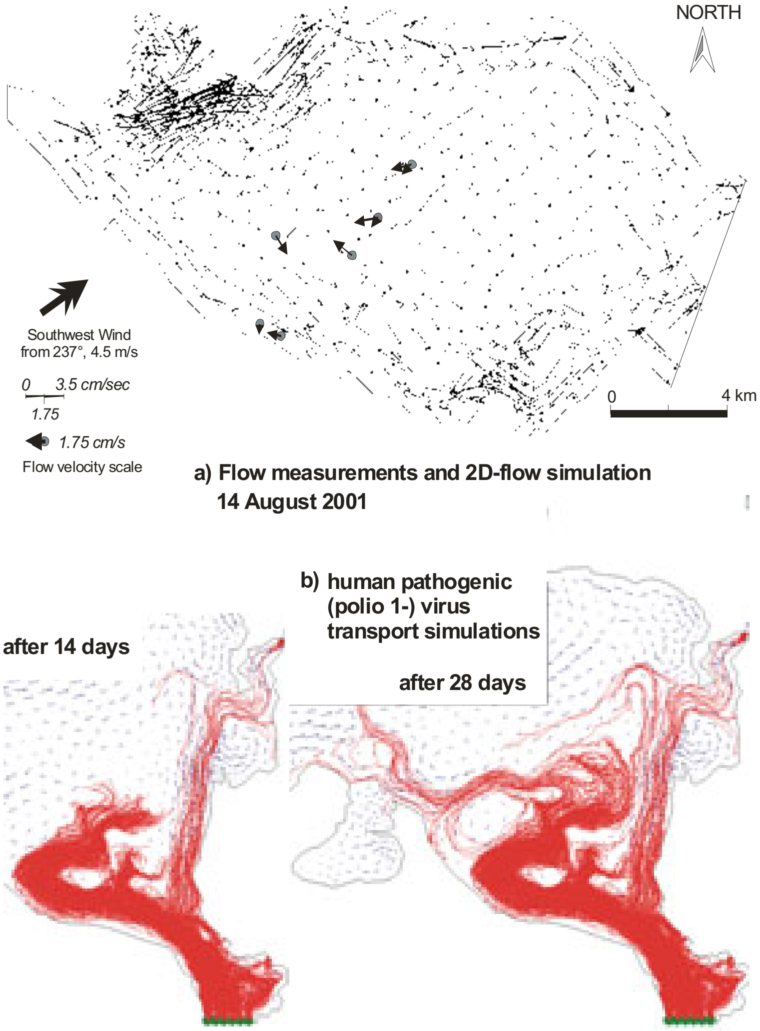

Figure 2. a) The simulated depth-averaged flow field as well as measured depth-averaged currents in the Szczecinski Lagoon (Small Lagoon) on 21 August 2001
b) Virus transport simulations.

Source for the human pathogenic viruses is poorly treated waste water of the city of Szczecin (Poland) that is released into the river Oder, 21 km upstream. Trajectories of particles indicating transport and decay of active (Polio-1) viruses attached to natural suspended particle matter in the Oder Lagoon under the conditions of 14 August 2001. The starting concentration was 10^4 viruses/m^3 water at the river mouth, attached to10^3 particles. After 14 days a concentration of 10^3 viruses/m^3 remained and after 28 days the number decreased to 10 particles (100 active virus/m^3). As a coarse approximation, one can say that all areas outside the range of the shown trajectories have no realistic infection risk at least during this concrete situation.

Our results clearly show that all beaches north of Szczecin along the river Oder as well, as in the river mouth. have a potentially high virus infection risk. Examples are shown in Figure 3. The fast virus decay suggests, that smaller pollutants like cities along the coast of the lagoon might be of higher importance than a heavy but more distant pollutant like the city of Szczecin. During the last decade, new waste-water treatment plants on the German side of the lagoon improved the quality of released waster water and decreased the risk of high virus release into the Small Lagoon. Recently new waste-water treatment plants with high capacity were established on the Polish side in Swinoujscie and Miedzyzdroje, too. Altogether, the adjacent towns nowadays have to be regarded as less important sources for viruses. Despite this, a local virus release can never be excluded.

Figure 3. Public beach in Luczyna in the Jezioro Dabie near Szczecin as well as in Stepnica close to the Oder River mouth

Referring to our results, summer tourists are subject to a serious virus infection risk in both locations.

Acknowledgement

The work was supported by the German Academic Exchange Service (DAAD PPP-Finland) and the IOW-Project "Oderhaff".

References

1. Boczar, J. and Szaniawski, A., 1993. Disposal and treatment of sewage and wastewater from Szczecin and its environs. In: Stan Srodowiska Miasta I Rejonu Szczecina. Societas Scientarum Stetinensis, pp. 325-326, Szczecin.
2. Dumke, R., and Feuerpfeil, I., 1997. Ergebnisbericht zum Statusseminar Dez. 1997 "Verhalten von Mikroorganismen und Viren bei der Trinkwasseraufbereitung" Hrsg. Forschungszentrum Karlsruhe GmbH.
3. Schernewski, G., and Jülich, W. - D., 2001. Risk assessment of virus infections in the Oder estuary (southern Baltic) on the basis of spatial transport and virus decay simulations. Int. J. Hyg. Environ. Health 203, pp. 317-325.
4. Podsetchine, V. and Schernewski, G., 1999. The influence of spatial wind inhomogeneity on flow patterns in a small lake. Wat. Res., 33, 15, pp. 3348-3356.
5. Wallbaum, V. and Rudolph, K.-U., 2000. Das Oder-Einzugsgebiet: Einträge durch Punktquellen und umwelt-ökonomische Untersuchungen. Meereswiss. Ber. 40, pp. 29-43, Warnemünde.

An integrated approach for a research project on management of transboundary waters in the EU-border region

Per Stålnacke
Jordforsk – Norwegian Centre for Soil and Environmental Research, Ås, Norway
Geoffrey Gooch
Department of Management and Economics, Linköping University, Sweden
Sindre Langaas
Department of Land and Water Resources Engineering, Royal Institute of Technology, Stockholm, Sweden
Gulnara Roll
Peipsi Center for Transboundary Cooperation, Tartu, Estonia

Introduction

It is widely accepted that water management should be based on an integrated approach, involving planners, scientists, policy makers and end-users. Management of transboundary waters is particularly complicated since there is not one Government to manage international waters and bordering states may have different languages, cultures, as well as different water management legislation and institutional structures. Moreover, the EU Water Framework Directive (WFD) [1], will become a central tool for the future environmental management of transboundary river basins in Europe. EU has recognised that the environmental problems being faced in the accession countries and beyond are far more severe than in the present Member States. Thus, there is need for a truly integrated and functioning basin-wide cooperative scheme for the management of international waters, especially in the future Eastern European border region.

In this paper we will elucidate the issue of integrated water management from the perspective of the research project "Integrated strategies for the management of transboundary waters on the Eastern European fringe (MANTRA-East) – the pilot study of Lake Peipsi and its drainage basin". Our approach is to develop and test the core elements of the project. These are (i) ecological problems; (ii) environmental information for decision-making; and (iii) policy instruments for decision-making under conditions of transition and uncertainty. Lake Peipsi, the largest international lake in Europe, is selected as a pilot region and an overview of the ecological and socio-economic problems and institutional arrangements in the pilot region are given.

The MANTRA-East project: a short description

The following three scientific objectives are defined:

- To evaluate the applicability of the EU WFD to the new future border regions, with regard to (i) assessment of the state of eutrophication (e.g. ecological status) in lakes and river basins; and (ii) development of strategic lake and river basin tools for source apportionment, retention, and time-trends in nutrient loads;
- To develop methods to improve communication and use of scientific information in a transboundary context;
- To develop institutional mechanisms and policy instruments for decision-making under conditions of transition and uncertainty.

[1] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, published in the Official Journal L 327 of 22/12/2000.

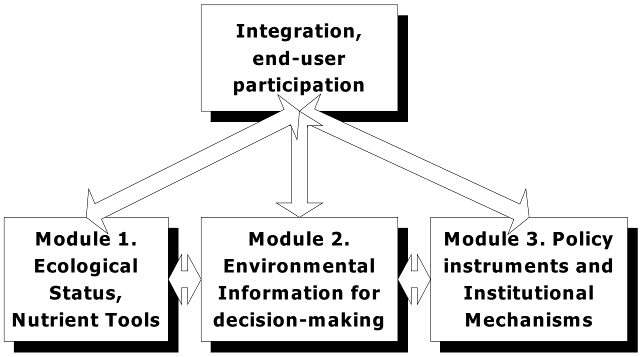

Figure 1. The 4 four research modules in MANTRA-East

The following methodologies and approaches will be used under each module (Figure1):

Module 1 – Ecological status and strategic nutrient tools

This module deals with the development of criteria and tools for assessing eutrophication in transboundary river basins in Europe. The research includes:

- Examination and evaluation of a set of the most informative monitoring parameters used in ecological status assessments, and calibration of the monitoring parameters in accordance with the water quality classes proposed in the EU Water Framework Directive (WFD), tested in the pilot study area of the Lake Peipsi and its drainage basin;
- Analysis of the trends in water nutrient quality and biota in lakes and their tributaries on the Eastern European fringe, with special emphasis on Lake Peipsi and its drainage basin, given the recent dramatic change in land use practices and industrial emissions in most of the Eastern European region;
- Further development and application of tools that can simulate the transfer, retention, and losses of nutrients in transboundary and data-poor river basins. The tools developed will be used to estimate the effect of changes in pollution sources (e.g. changes in agricultural land use) on the nutrient inputs to Lake Peipsi;
- Evaluation of the lake response to the recent dramatic and large-scale changes in river pollution loads of nutrients in the drainage basin of the Lake Peipsi. Analysis of the in-lake response to different scenarios of future changes in river basin management on the nutrient input to the lake and estimation of the influence of different activities in the river basin on lake water quality and biota, including fish, will also be performed.

Module 2 – Environmental information for policy and decision makers

It has earlier been found that 80% of the work of transboundary water management institutions is devoted to various types of information activities, mainly related to monitoring activities. This large percentage is in contrast with national water management in where a much higher percentage is devoted to implementation activities. The objective is to investigate the use and role of environmental monitoring, database development, information generation and communication for policy- and decision-making and management within a limited number of European transboundary river basins. Under this module, we will conduct a review of information management models used in different transboundary river basins in Europe that are managed in different political and economic settings and that have different priority environmental issues. Guidelines on requirements for information management systems, for different transboundary river basins located on the borders of the European Union, and a demonstration prototype of an information system for the pilot region – the Lake Peipsi river basin – will be developed. In parallel a multi-thematic (socio-economic and environmental) GIS database for the Lake Peipsi and its drainage basin composed of 10-15 thematic layers relevant for modelling, assessment, strategic decision-making, existing management structures and the general public will be developed. Furthermore, for the dissemination of the data sets and easy access, an interactive web GIS will be set up.

Module 3 – Policy instruments and institutional mechanisms

This module will be comprised of studies of institutional mechanisms and policy instruments for decision-making under conditions of transition and uncertainty. Transboundary water management policy needs to promote the establishment of clear institutional framework for rights and duties related to water. Given the disparities between local areas, institutional responses to water rights and pollution disputes need to be analysed, and the possibilities of setting these disputes within existing local water users' associations need to be evolved, thereby complying with the subsidiary principle and preparing for the implementation of the EU WFD. The objective of the work under policy analysis module is to conduct a comprehensive, theoretically informed, and in-depth review of existing management structures, models and practices that have been used, are used, or are planned to be used in transboundary water management in Europe. The work will take into account the varying problems and forms of management in the different European regions and will contribute new knowledge on this crucial issue. The results of the work will provide important knowledge and information for European policy makers as well as for European water management practitioners.

Module 4 – Integration, synthesis and end-user participation

The fourth module will produce decision support appropriate to end-users through integration and synthesis of the work under modules 1-3 and end-user participation. This work includes:

- An integrative approach and synthesis of the results, promoting the introduction of an operational framework for strategies and tools for the management of transboundary waters on the Eastern European fringe;
- Project management, including the dissemination of results to stakeholders, the public and end-users, including the involvement of an Advisory Committee throughout the entire project.

This will be performed by the development of integrated scenarios that will be used in the 3 main modules. The scenarios will be developed by the research team jointly with the end-users, e.g., by involvement of citizen jury.

Some of the proposed activities will be addressed and explored in a concrete context using the Lake Peipsi region as a pilot region. Even though the work focus upon this region, it is still considered to be of pan-European interest, and results will deliberately have a high degree of transferability and general validity. It is thus a deliberate research strategy that the results obtained, tools developed, and strategies evaluated can be transferred to other transboundary lakes and river basins on the Eastern European border region.

The pilot study of Lake Peipsi and its drainage basin

Lake Peipsi (Figure 2), the largest international lake in Europe, is selected as a pilot region. It is shared by one EU accession country (Estonia) and one non-EU country (Russian Federation), and thus of high relevance for the future environmental management of transboundary waters on the European fringe.

The ecological and socio-economic situation

Lake Peipsi has a combined surface area of 3,550 km^2 and is the fourth largest lake in Europe after Lakes Ladoga, Onega, and Vänern (Stålnacke and Roll, 2002). The catchment area totals approximately 44,000 km^2; 59% is located within the Pskov Oblast, 34% is within the territory of Estonia and 7% is within Latvia. The Narva River – which after the River Neva is the second largest river flowing into the Gulf of Finland – is about 77 km long. Agricultural land and forests cover respectively 42% and 40% of the total drainage basin (Vassiljev and Stålnacke, 2002).

Figure 2. The Lake Peipsi drainage basin and its major rivers. Source: Hannerz et al (2002)

There are two major towns in the catchment area, located in the central and south-eastern part of the catchment: Tartu in Estonia with 98,000 inhabitants and Pskov on the Russian side with 200,000 inhabitants. In the rural and sparsely populated areas outside these two main towns, typical activities are based on milk and cattle farms, small-scale fishery, timber enterprises and food processing factories. Since agriculture is not profitable today in the Russian territory in the lake catchment, many local people live by felling timber and selling the wood. Good peat reserves are to be found in the lake catchment, but they are not exploited for lack of demand. Tourism and recreation are largely undeveloped because of a poor infrastructure, a sensitive coastal zone and weak public transport. Thus the main environmental issues in the rural areas are impacts from timber felling and diffuse agricultural pollution.

In contrast with the above, the most northern area is dominated by the use of the main mineral resource of the area – oil shale. Two of the world's largest thermal power plants, consuming the oil shale, are located in Estonian territory. Together with various enterprises and the discharges of domestic waste water awaiting the completion of biological treatment stages in Tartu and Pskov, these activities cause a significant polluting impact on Lake Peipsi. Coupled with this and some 18 km downstream from the lake, a 125 MW hydropower plant has been constructed on the Narva River. There is a reservoir nearby the hydropower plant, which contains cooling water for the thermal power plants mentioned earlier. The smaller communities living around the lake rely on commercial and small-scale fishing for their income.

In the economic recession that followed the demise of the Soviet Union, the use of commercial fertilisers in most Eastern European countries began to decrease at an unprecedented rate (Stålnacke et al., 2002b). In the Lake Peipsi drainage basin, it has been estimated that the use of mineral fertilisers has decreased by about 7-8 times and the number of pigs and cattle has reduced by about a half (Stålnacke et al., 2002b). Moreover, the import of feedstuff became almost nil. Such abrupt and substantial changes in land use have rarely been recorded in the history of modern European agriculture, and they have created unique opportunities to study the impact of agricultural practices on water quality. It seems that the nitrogen loading has decreased while phosphorus loads remain at previous levels or at least show a much weaker trend than nitrogen.

It has been estimated that the lake via its rivers received some 20,500 tons of nitrogen and 910 tons of phosphorus as annual mean between 1995 and 1998 (Stålnacke et al., 2002a). Results indicate that less than 10% of the nitrogen load from Estonian rivers to Lake Peipsi originates from waste water (point pollution sources); approximately 60% of the load come from agriculture and 30% originates from forests and other diffuse sources (Vassilijev and Stålnacke, 2002). Of the phosphorus load, over 40% come from point pollution sources and almost 40% from agriculture via the rivers in the catchment area (Vassilijev and Stålnacke, 2002).

Eutrophication could seriously affect the lake potential for supporting important European habitats for wildlife, especially birds, as a resource supporting commercial fisheries, and as a focus for tourism and recreation activities. The first assessment of the ecological status of Lake Peipsi according to the WFD shows that chlorophyll, phosphorus and macroinveretebrates reflect mostly good status while phytoplankton, Secchi depth, nitrogen and fish fauna reflect the situation rather fair than good. In addition, it was concluded that there is a need to develop type-specific or even lake-specific criteria system especially for large non-stratified lakes. Moreover, the decline in loadings has not yet been sufficient to reverse the situation and eutrophication is still recognised as a major threat to the water quality of the lake. More precisely, analyses of water quality data in Lake Pepsi have showed: (i) a biological resilience in response to reduced nutrient level in the 1990s (ii) phytoplankton groups that demands less nutrients as cyanobacteria have become more dominating (iii) the ecosystem is affected by large natural inter-annual water level fluctuations (Kangur et al., 2002).

Commercial fisheries, supported by a healthy fish stock, are an important activity both on the Russian and Estonian sides of the lake. Fish stocks are one of the best of any lake in Europe. The total catch of fish in Lake Peipsi-Pihkva has declined. However, the value of catch is at approximately the same as in 1935-1940 and 1971-1990 (Saat et al., 2002; Vetemaa et al., 2002). In spite of different approaches to fishery and management goals in Estonia and Russian Federation, the joint management of commercial fish resources has been successful in avoiding overfishing. A recent inventory by Tambets et al. (2002) also indicates that there exists a bream population in Lake Peipsi that spawns in meanders of the Emajõgi River (up to 90 km from the river mouth) and migrates for feeding in Lake Võrtsjärv. During the last decade, abundance of this population has been high, and specimens of this population have formed a remarkable proportion of commercial catches of bream from Lakes Peipsi and Võrtsjärv.

The future control of the discharges of nutrients from the rivers will thus be important for the ecological status of the lake. It cannot be ruled out that the nutrient loads will increase in the near future due to an economic recovery in the region, particularly in relation to agriculture. On the other hand, recent estimates indicate that the agricultural land in Estonia will decrease by some 20-25% (Sepp, pers. comm.). At the same time, the share of forests will remain the same, as clear-cuts compensate the increase in the area.

The legal and institutional arrangements

The border between Estonia and the Russian Federation, where Lake Peipsi is located, has, since the political changes of 1989 and later, presented a particular challenge in respect of the implementation of harmonized environmental protection policies, strategies and actions. The return to traditional cross-border cooperation after several decades of poor relationships under the former Soviet regime is a slow process. On the one hand, Estonia is undergoing changes, institutionally, economically and socially, to become a new member of the European Union. This will involve implementation of new environmental legislation to conform to European Community Directives and Regulations. On the other hand, the Russian Federation is making significant changes to its institutional structure in Government at all levels, in a period of economic difficulty, to enforce and implement improvements in its environmental legislation, responsible organizations and administration. The situation requires to be examined and measures implemented to allow for cross-border harmonization, so that management practices can be evenly applied for the benefit of the communities dwelling in the region.

Financial constraints as well as problems of communications and languages present major obstacles to the development of legal and administrative arrangements between the two countries. Differences in environmental planning and management capacities further complicate matters with the application by Estonia to join the EU posing a challenge for the harmonization of legislation, policies and standards common throughout the EU with those applied in the Russian Federation. As a result the pursuance of joint policy action in the cross-border region represented by the catchment of Lake Peipsi is not making the progress the situation requires.

Currently, at the bilateral level, Estonians and the Russians have signed two agreements of direct relevance to the management of the lake:

- Agreement on the Protection and Regulation of the Use of Fish Resources of Lake Peipsi, Lake Lammi, and Lake Pihkva signed in May 1995 in Pskov, Russian Federation;
- Joint Agreement on Transboundary Waters signed in August 1997. In 1998 a Joint Commission was established which scope included: (i) organization of the exchange of monitoring data between the Parties in accordance with the agreed monitoring programme; (ii) definition of priority directions and programmes of scientific studies on protection and sustainable use of transboundary waters; (iii) agreement on common indicators of quality for transboundary waters, methods for water quality assessment and conducting analyses; (iv) coordination of the work of the competent agencies of the Parties when extraordinary situations occur on the transboundary waters; and (v) facilitation of cooperation between executive agencies, local Governments, scientific and public interest organizations, as well as other institutions in the field of sustainable development and protection of transboundary waters, ensuring that due publicity is given to discussions of questions related to the use and protection of the transboundary waters.

The Commission has established four working groups: on Water Economy, Water Protection, Monitoring and Research and on Cooperation with International and Non-Governmental Organizations and Local Authorities. Signing this bilateral Agreement and establishing the Commission opens a window of opportunity for implementing research activities and for preparing an action plan for protecting the lake’s resources.

Apart from eutrophication, there are other cross-border environmental problems that require attention. One example is the unsettled dispute over the water supply and waste-water treatment facilities for the towns of Narva (Estonia – 79,000 inhabitants) and Ivangorod (Russian Federation – 12,000 inhabitants). The towns had common facilities, as they were one town before the demise of the Soviet Union. The waste water of Ivangorod was pumped to the Narva waste-water treatment plant and Narva supplied drinking water to Ivangorod. The municipality of Ivangorod, however, has a difficult financial situation and, as a result, payments for the service were below the amounts charged and the Estonian side stopped supplying potable water and receiving waste water. As a result, Ivangorod with the support of the Russian Government put in place an independent water supply system and is completing its water treatment facilities. Ivangorod is examining the possibility of abstracting water from local groundwater sources to improve water supply, but this would be the same aquifer that Narva uses. Another conflict could arise on this issue.

Discussion

Policy makers and managers have for a long time regarded water quality issues as mainly having one specific cause and generally one straightforward solution for the pollution problem. Today, it is generally accepted that water-related problems are far more complex and problematic, due to the simple fact that cause and effect relationships and abatement strategies are no longer independent of each other. For example, pollution problems are often interrelated with environmental change and socio-economic development to such an extent that a single disciplinary or sectoral approach can no longer provide a satisfactory solution. Another example is that water-quality issues related to surface waters are now being correlated to both hydrological concerns and terrestrial biogeochemical processes, including land use change and other basin-wide anthropogenic issues. Another aspect of this problem is the conflict between social and economic development on one side and environmental and pollution concerns on the other. Water policy analysts have therefore increasingly come to recognise that managing water resources can no longer be regarded as an independent field of expertise and a separate domain of public policy. It is now accepted that the interconnections between water systems, other aspects of environmental systems, and human systems, are extremely important areas of study. Thus, it is clear that water management should be based on an integrated approach, involving planners, scientists, policy makers and end-users. Even though integrated water resource management is currently practised in many regions worldwide, we still have not been able to “solve” pollution problems, and examples of “success stories” are difficult to find. Gooch et al (2002) showed that there is an emphasis on different tools or policy-styles in the case of integrated water management, but that integrated water management is primarily understood as a national level policy area. Furthermore the authors emphasise that integrated water management at the international level is usually not explicitly mentioned, and the local level is not always sufficiently taken into account.

Several lakes and rivers cross the boundaries between countries. Management of transboundary waters is particularly complicated since there is not one Government to manage international waters and bordering states may have different languages, cultures, as well as different water management legislation and institutional structures. The number of agreements on transboundary waters in Europe is approximately 160 and shows an increasing trend. Because of the enlargement preparations for the European Union, management of transboundary waters has received considerable attention lately. The EU Water Framework Directive (WFD), will become a central tool for the future environmental management of transboundary river basins in Europe. It has been recognised that:

- The environmental problems being faced in the accession countries are far more severe than in the present Member States;
- A gap between levels of environmental protection in present and future EU Member States would distort the functioning of the single market;
- Realistic national long-term strategies for gradual effective alignment with the EU countries should be drawn up and be implemented in all accession countries before accession, in particular strategies for tackling water and air pollution;
- The move from “pollution reduction” to “pollution management” requires in-depth research and policy cooperation;
- The EU has recognised and stressed the importance of not importing border conflicts to an enlarged Union;
- The reinforcement of institutional and administrative capacity is a common problem for the accession countries and a key problem in the enlargement preparations;
- There is a need for a truly integrated and functioning basin-wide cooperative scheme for the management of international waters, especially on the Eastern European fringe;
- Information-related issues have hardly been addressed scientifically at the international, transboundary level in Europe before;
- Transboundary water management presents a significant number of major challenges to politicians, planners, administrators and scientists. In order to meet these challenges, policy makers need access to reliable and relevant information, not only concerning the physical attributes of water systems, but also concerning the special political and administrative conditions that characterise transboundary water policy-making and implementation (Gooch et al., 2002);
- There is a lack of well-developed research and analysis on the implementation of water management policies and plans and organizational aspects of implementing EU water policy (political, research, administration, etc.) and problems of communication and information exchange between different levels of governance as well as across borders present major difficulties in this policy implementation (Gooch et al., 2002);
- On transboundary waters located on the future EU border, a growing gap in the formal frameworks (different administrative structures, norms and standards), practices, and information between different sides of the border – an EU member or accession country and a non EU State – present the major challenge of transnational implementation of EU water policy (e.g. WFD);
- The study by Gooch et al (2002) on theoretical models and a review of experiences of stakeholder and public participation in transboundary water management confirmed that involving multiple stakeholder groups in the development and implementation of EU and national water policies is critically important. However, this is not always feasible for various reasons. Traditionally, a major bottleneck in the implementation of environmental policies is created when experts produce a highly technical body of information that becomes incomprehensible to non-experts. Therefore, innovative approaches and technologies (e.g. semantic webs, citizen’s jury) must be developed and implemented in order to overcome this situation;
- Environmental data is rarely used in the decision-making process as long as it does not show a direct and clear connection between and impact of the physico-chemical and biological conditions to changes in the economic and social situation in a given transboundary water region (Timmerman et al, 2002);

- Results by Nilsson et al. (2002) show that transboundary commissions are largely expert/technical commissions. The socio-economic connotation of water management decisions may as a consequence be underestimated. One consequence is the minor attention of transboundary commissions for involvement of stakeholders;
- In transboundary river basins, riverine load modelling and source apportionment is more difficult than in other situations, because the required administrative statistics and GIS (spatial) data are not harmonious for each country (Mourad and van der Perk, 2002). This is especially the case for the Lake Peipsi basin, which can be regarded as data-rich for the Estonian and Latvian part, and data-poor with respect to the Russian part;
- All this clearly indicates that integrated water management, especially in transboundary regions on the EU border region is far from being an easy task. In MANTRA-East we have decided to base our integrated analyses on: (i) ecological problems; (ii) environmental information for decision-making; and (iii) policy instruments for decision-making under conditions of transitions and uncertainty. Development of integrated scenarios will form the basis for the integration.

Conclusions

There is a need for a truly integrated and functioning basin-wide cooperative scheme for the management of international waters, especially on the Eastern European fringe, an issue hardly addressed scientifically at the international, transboundary level in Europe before.

Therefore, there is an urgent need to develop innovative approaches and integrated strategies for the management of transboundary waters on the Eastern European fringe, which are the points of departure for the MANTRA-East project. The Lake Peipsi basin is a major basin in northern Europe and is likely to become part of the new frontier between the EU and the Russian Federation. Results obtained from the pilot study area indicate that integrated water management will be difficult to achieve and there are various obstacles, such as differences in water management legislation, institutional structures and practices that stem from differences in languages, cultures as well as physical and political geography of the two States. The future socio-economic development in the region will affect the water quality and ecology of the lake, the latter an issue which is difficult due to the complex cause and effects relationships. An integrated analysis of the relationships between (i) ecological problems; (ii) environmental information for decision-making; and (iii) policy instruments for decision-making under conditions of transitions and uncertainty is regarded as the first step for successful management of transboundary waters on the EU-border region.

References

1. Alcamo, J., 2001. Scenarios as tools for international environmental assessments. European Environment Agency Report No. 24.
2. Gooch, G. D., Höglund, P., Roll, G., Lopman, E. and Aliakseyeva, N., 2002. Review of existing structures, models and practices for transboundary water management in Europe – The implementation of transboundary water management – identification of present problems and a design for future research. In: Proceedings of the Second International Conference: Sustainable Management of Transboundary Waters in Europe, Miedzyzdroje, Poland, 21-24 April 2002. (this issue).
3. Hannerz, F., Langaas, S., D., Nilsson, S., Tian, Y., 2002. A multi-thematic GIS database of the transboundary Narva River / Lake Peipsi catchment in support of strategic science and management applications. MANTRA-East report No. 8a,. 50 pp.
4. Kangur, K., Milius, A., Möls, T., Laugaste, R., Haberman, J., 2002. Lake Peipsi: Changes in nutrient elements and plankton communities in the last decade. Journal of Aquatic Ecosystem Health and Management (accepted).
5. Mourad, D., and van der Perk, M., 2002. Modelling Nutrient fluxes from diffuse and point emissions to river loads: the transboundary Lake Peipsi / Chudskoe basin (Russia / Estonia / Latvia). In: Proceedings from the 6th International Conference on Diffuse Pollution, Amsterdam, the Netherlands, 30 September - 4 October 2002. pp. 259-266.
6. Nilsson, S., Langaas, S. and Gustafsson, J-E., 2002. A comparative study of environmental information management in some transboundary water regimes (in prep.)

7. Saat, T., Vaino, V., Afanasjev, G., Koncevaya, N., 2002. Fisheries and fisheries management on Lake Peipsi-Pihkva. In: Cowx, I. (ed.), Management and Ecology of Lake and Reservoir Fisheries. Oxford, Fishing News Books, Blackwell Science Ltd, pp. 322-331.
8. Stålnacke, P. and Roll. G., 2002. Lake Peipsi – a transboundary lake on the future border of the European Union. In: Hedegaard, L. and Lindström (Eds.), The NEBI Yearbook 20021/2002. Springer-Verlag Berlin Heidelberg. pp. 159-176.
9. Stålnacke, P., Sults, Ü, Vasiliev, A., Skakalsky, B., Botina, A., Roll, G., Pachel, K. and Maltsman, T., 2002a. Assessment of riverine loads of nutrients to Lake Peipsi, 1995-1998. Arch. Hydrobiol. Suppl. Large Rivers (in press).
10. Stålnacke, P., Vandsemb, S. M., Vassiljev, A., Grimvall, A. and Jolankai, G., 2002b. Changes in nutrient levels in some Eastern European rivers in response to large-scale changes in agriculture. Water, Science and Technology (submitted).
11. Tambets, M., Vetemaa, M., Tambets, J., Järvekülg, R. and Saat, T., 2002. Impact of tributaries to the status of lake fish fauna (manuscript).
12. Timmerman, J. G., Kipper, K., Meiner, A., Mol, S., Nieuwenhuis, D., Roll, G., Säre, M., Sults, Ü. and Unt, P., 2002. The use and valuing of environmental information in the decision-making process: an experimental study. In: Proceedings of the Second International Conference on Sustainable Management of Transboundary Waters in Europe, 21 - 24 April 2002, Miedzyzdroje, Poland (this issue).
13. Vassiljev, A. and Stålnacke, P., 2002. Source apportionement of nutrients in the Lake Peipsi drainage basin – experiences from a statistical model. Water Science and Technology (submitted).
14. Vetemaa, M., Vaino, V., Kuldin, S., Saat, T., 2001. Cooperative fisheries management of transboundary Lake Peipsi-Pihkva. Fisheries Ecology and Management 8, pp. 443-451.

Investigation of cyprinid spawning grounds and conditions for sustainable fish management of Lake Ohrid

Trajce Talevski and Marina Talevska
Hydrobiological Institute, Ohrid, the former Yugoslav Republic of Macedonia

Lake Ohrid is the biggest and the deepest lake in the Dassaret lake group of the Aegean lake zone. It is "a museum of living fossils" and represents a refuge for numerous freshwater organisms with congenital species that can only be found in the wider region of the Balkan Peninsula and Central Europe in fossil form. Lake Ohrid is a transboundary water body, and one of the largest lakes in Europe (Stankovic, 1960).

Lake Ohrid is located in the Shar-Pindos carstic massif in the former Yugoslav Republic of Macedonia (41^o 05' N, 20^o 45' E) and Albania. The lake is of tectonic origin and has been formed in Pliocene along two cut-up lines (almost meridian shape) in the direction of Struga - Starova in the west and Kosel - Ljubanista in the east. It is more than two million years old.

At a sea level of 693.17 m, Lake Ohrid has a surface area of 358.18 km^2 of which 2/3 (about 238.79 km^2) belongs to the former Yugoslav Republic of Macedonia and 1/3 (about 119.39 km^2) belongs to Albania; a shore line of 87.53 km; a maximum length of 30.48 km; a maximum width of 15 km; a maximum depth of 288.7 m; a mean depth of 163.71 m; and a volume of 58,64 km^3 with a retention time of about 80 years (Naumoski, 1985).

About 40 tributaries flow into the lake: 23 in Albania and 17 in the former Yugoslav Republic of Macedonia, most of them being torrents, flowing only during heavy rains and snow melt. Main tributaries in the former Yugoslav Republic of Macedonia are the rivers Sateska, Koselska, Velgoska, Cherava and the outflow of St. Naum springs.

The littoral region of Lake Ohrid (in certain northern and southern areas) extends to 1.5-2 km, but in the western and eastern areas of the lake it is even less than 10 m.

The macrophyte vegetation, which is found throughout the littoral zone of Lake Ohrid, is represented by vascular plants, a small number of aquatic mosses and some algae. In Lake Ohrid, macrophyte vegetation is not richly developed, especially in the upper littoral, where it can mainly be observed near the shore not so much exposed to winds and less beaten by the waves. It always presents vertical zonal reparation. Few zones (belts) of macrophyte vegetation can be distinguished in Lake Ohrid (Jakovlevic, 1936):

- Belt of Cladophora sp.;
- Belt of reed, Phragmites communi;
- Belt of pondweed, Potamogeton;
- Belt of stonewort, *Chara.*

The nearest to the shore is the belt of *Cladophora sp*., which forms a continuous belt around the whole lake. This belt serves as a habitat for a large number of organisms in the littoral zone of the lake, and a breeding site for bleak *Alburnus alburnus alborella* Fillipi, grunec *Rutilus rubilio ochridanus* Karaman, and moranec *Pachichylon pictum* Heck&Kner.

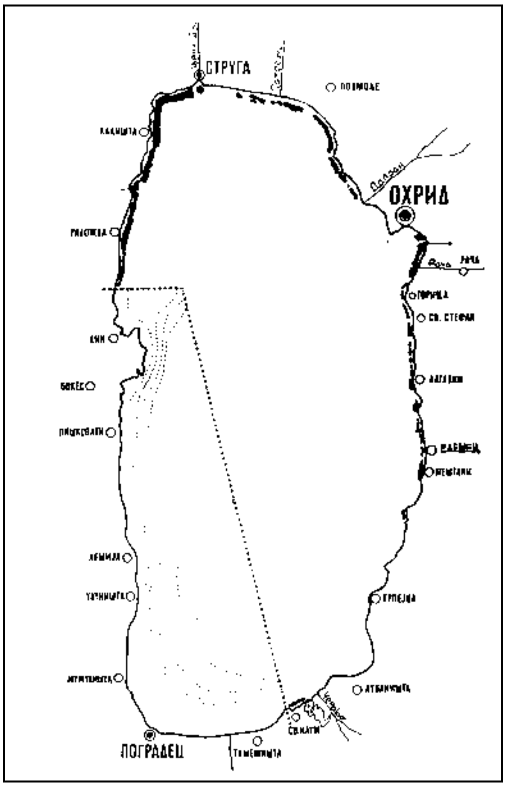

Figure1. Belt of reed, *Phragmites. Communis* from Lake Ohrid (Original)

The Belt of reed, *Phragmites communis,* is made up of 105 particular complexes with different areas (Figure 1). The belt along the shore of the former Yugoslav Republic of Macedonia (Radozda-Sv.Naum) has a total length of 14,833 m and a surface area of 743,500 m^2 (Talevska, 1996). Several other emergent plants are present in the belt of reed: *Typha latifolia, Typha langustifolia, Scirpus lacustris* and others. The reed zone occupies the bottom of the upper littoral, between 1.5 and 4 m depth. This belt serves as a habitat for a large number of organisms in the littoral zone of the lake, and is a breeding site for many species of fish and aquatic birds.

The Belt of pondweed, *Potamogeton,* is much better developed as a belt of reed and is almost continuous. The species *Potamogeton perfoliatus* predominates and forms sometimes almost pure associations. To the *Potamogeton perfoliatus* other submerged plants are associated, such as *Potamogeton pectinatus, Potamogeton lucens, Potamogeton crispus, Myriophillum spicatum, Ceratophyllum demersum, Vallisneria spiralis, Zannichellia palustris, Najas major* and others. The zone occupies the bottom between 4 and 6 meters depth. This belt provides food and shelter to many organisms in the littoral zone of the lake (zooplankton, invertebrates, fish, wild fowl and others).

The Belt of stonewort, *Chara*, is the deepest belt of vegetation. It forms a wide continuous belt, which occupies the bottom of the lower littoral between 6 and 15 and even 21 meters depth. This belt serves as a habitat for a large number of organisms of the lake.

Materials and methods

A cast net was used for daytime fishing with a mesh size of 13 mm. The nighttime fishing was performed with bleak nets (mesh sizes 12 mm and 13 mm), barbel nets (mesh sizes 22 mm, 24 mm, 26 mm and 28 mm) as well as nets with mesh sizes of 45 mm and 50 mm. The height of each fishing gear is basically a hundred heights per each mesh, and the length is about 50 meters.

In the course of 2000 and 2001, 28 experimental fish catches were performed during the spawning period of the cyprinid ichthyofauna, i.e. April, May, June, July and August.

Collections of macrophyte vegetation were made from 13 sites from the eastern and south-eastern littoral of Lake Ohrid: Ljubanista, Trpejca, Gradiste, Elesec, Lagadin, Metropol, Granit, Sileks, Mazija, Grasnica, Daljan, Andon Dukov and Podmolje.

In the course of 2000 and 2001, the main objective was to investigate the spawning fish grounds of economic-important fish species, dominant in the Ohrid cyprinid ichthyofauna. These include the species bleak *Alburnus alburnus alborella* Fillipi, balkan barbel *Barbus meridionalis petenyi* Heckel, Ohrid undermouth *Chondrostoma nasus ohridanus* Karaman, grunec *Rutilus rubilio ochridanus* Karaman, Ohrid chub, *Leuciscus cephalus albus* Bonaparte and the zoogeographically significant species moranec *Pachichylon pictum* Heck&Kner, which is an endemic and a relict species for Lake Ohrid, the River Crn Drim and Lake Skadar. The sex composition of the experimental catch was also determined.

Collections of macrophyte vegetation were made by the standard limnological methods (Katanska, 1956; Lind, 1979). The collected materials were examined under laboratory conditions according to the respective flora and keys.

Results and discussions

The composition of the experimental catch at the respective sites and periods of the experimental fishing varies and depends on the fishing gear used for the experimental fishing, the type of the ground and the overgrowth of the lake bottom with macrophyte vegetation, the weather conditions during which the fishing was performed as well as many other factors that influence the qualitative and quantitative composition of the experimental catch.

Bleak, <u>Alburnus alburnus alborella</u>, Filippi

The results obtained in the course of 2000-2001 point to a higher percentage of female individuals in relation to male individuals. The analysis of the data for 2000 clearly displays the fact that the female individual population significantly overwhelms the male population. This particularly refers to the period when the bleak population stops to spawn in the littoral zone of Lake Ohrid. This proportion is 77.3% female individuals to 22.7% male individuals in the month of May of the corresponding year (Figure 2).

The results for 2001 also prove the previous conclusion that the population of female individuals is higher in percentage than the population of the male individuals. The maximum difference in bleak population regarding the sex composition has been observed in the month of April when the female individuals in the experimental catch were present with 70.3% and the male individuals with 29.7%, whereas in the month of June the sex composition was 60.9% female individuals, and 39.1% male individuals (Figure 2).

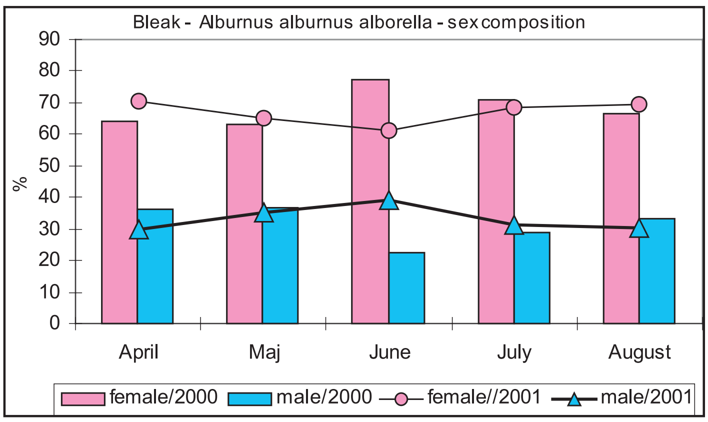

Figure 2. Monthly fluctuations in male and female individuals of bleak *Alburnus alburnus alborella* in Lake Ohrid at the investigation sites in the course of 2000 and 2001

In the course of the two investigation years, the population of the female individuals significantly surpassed in number the population of male individuals, a conclusion that had already been reached in our previous investigations, not to mention the research of a great number of authors who had investigated the dynamics of cyprinid species in Lake Ohrid. This difference appears in the period when the bleak stops to spawn in the littoral zone of Lake Ohrid. Provided the analysis would have covered a period of more years and would have included more samplings in the course of these years, the number of the male and female individuals would become as equal as 50:50, i.e. the sex composition would be balanced (Talevski, 1997, 1998a, 1998b, 2001).

Moranec, Pachychilon pictus Heckel & Kner

The changes of the sex composition in the moranec population have been monitored at the time when the moranec individuals are in the pre-spawning period, during the spawning and after the spawning season in 2000 and 2001.

The results gained from the analysed material in the course of 2000 show that the moranec, as it was expected, complies with the results obtained for the other cyprinid fish. The results clearly demonstrate that for moranec population, likewise, the female individuals exceed the male individuals in number. The most obvious difference in view of the number of female and male individuals takes place in July when the females are present with 64.1%, and the males with 35.9%, whereas the difference considering the participation number of the female and male individuals is very small in April when the female individuals are represent by 57.7%, and the male individuals by 42.3% (Figure 3).

Investigations of the moranec population during the period of 2001 revealed that the female individual population greatly surpassed in number the corresponding male individual population. This proportion is the biggest in the month of April (78.4% female individuals to 27.6% male individuals), whereas the figures for May are 63.3% female individuals to 36.7% male individuals (Figure 3).

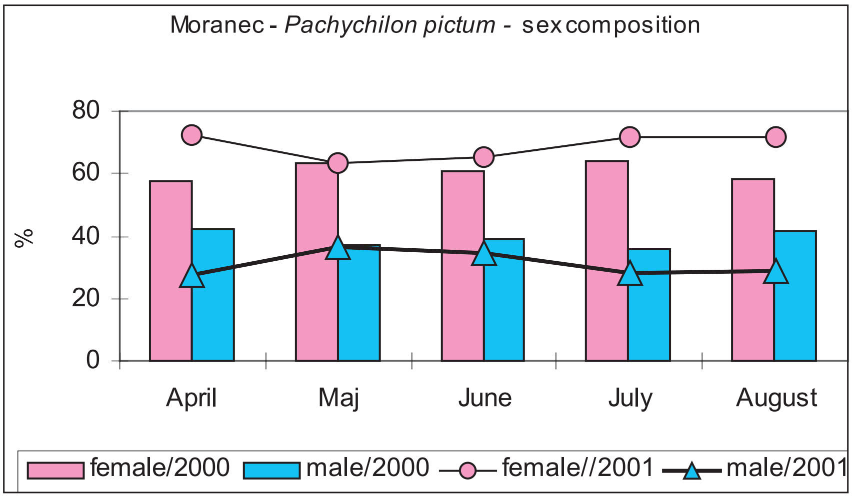

Figure 3. Monthly fluctuations in the male and female individuals of moranec *Pachychilon pictus* in Lake Ohrid at the investigated sites in the course of 2001 and 2001

Balkan barbel, Barbus meridionalis petenyi

The investigations of the sex composition of Balkan barbel in Lake Ohrid point to a higher percentage of female individuals in the analysed material of the experimental catch: during the two investigated years, the monthly share of male and female individuals was in favour of the female individuals. The biggest difference in the course of 2000 was observed in June and the proportion was 73.6% female individuals to 26.4% male ones. As far as the year 2001 is concerned, the biggest difference in sex composition appears in July (71.1% female individuals to 29.9% male individuals). The smallest difference in monthly experimental catches in barbel occurs in June (60% to 40% in favour of the female individuals). In the course of 2001, this proportion increased to 63.3% female individuals compared to 36.7% male individuals, observed in May (Figure 4).

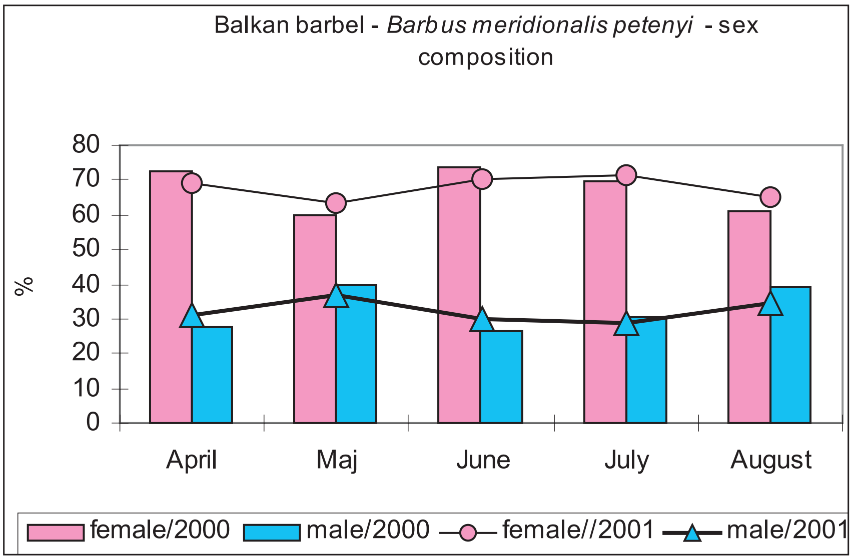

Figure 4. Monthly fluctuations of male and female individuals of barbel *Barbus meridionalis petenyi* in Lake Ohrid at the investigated sites in the course of 2000 and 2001

Undermouth, <u>Chondrostoma nasus ohridanus</u>

The results gained from the analysed material in the course of 2000 and 2001 show a relatively high percentage of female individuals in comparison to the male individuals. In the course of the corresponding year 2000, the proportion of females was 68.6% to 31.4% males in July, and in May 57.5% to 42.5%. In the following year 2001, the proportion was furthermore evened out: in July, the sex proportion was 73.1% female individuals to 26.9% male individuals. The ratio in May was 64.4% female individuals to 35.6% male individuals (Figure 5).

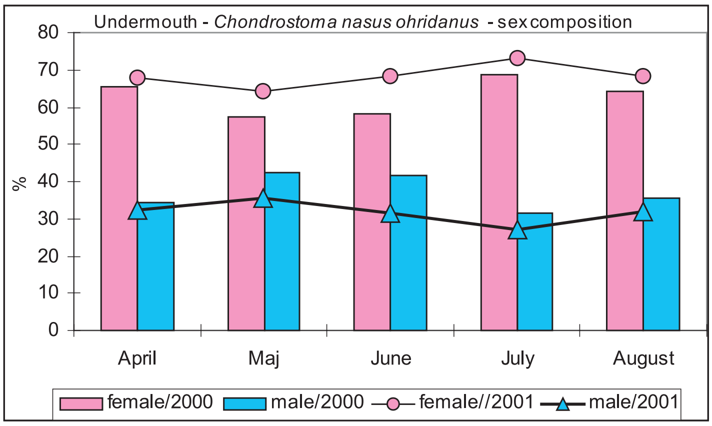

Figure 5. Monthly fluctuations of male and female individuals of undermouth *Chondrostoma nasus ohridanus* in Lake Ohrid at the investigated sites in the course of 2000 and 2001

Grunec, <u>Rutilus rubilio ohridanus</u>

The obtained results from the analysed material in the course of 2000 and 2001 demonstrate the fact that during the two years of investigation, the number of the female and male individuals varies to a great extent and was always in favour of female individuals.

The year 2000 displayed the biggest differences in the sex composition in August when the female individuals were determined as 72.3%, compared to the males with 27.3%, and the smallest difference was detected in June when the populations of both female and male individuals were nearly balanced (female individuals 54.1%, and male individuals 45.9% as shown in Figure 6).

The investigations of 2001 once more showed that the closest proportion between the female and male individuals in May is a recurrent characteristic of the sex composition (female individuals 55.2%, males 44.8%). The biggest difference in the sex composition occurs in April when the female individuals were present with 71.1% and the males with 28.9% (Figure 6).

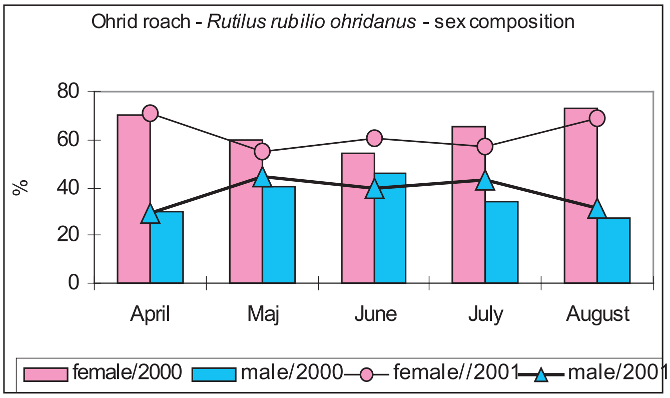

Figure 6. Monthly fluctuations of male and female individuals of grunec *Rutilus rubilio ohridanus* in Lake Ohrid at the investigated sites in the course of 2000 and 2001

Chub, <u>Leuciscus cephalus albus</u>

The chub *Leuciscus cephalus albus* population has been investigated in the course of 2000 and 2001. Similarly to other cyprinids, the chub also reveals a relatively higher percentage of female individuals. This can be most explicitly seen in Figure 7, where the sex composition of the chub population in 2000 and 2001 are presented.

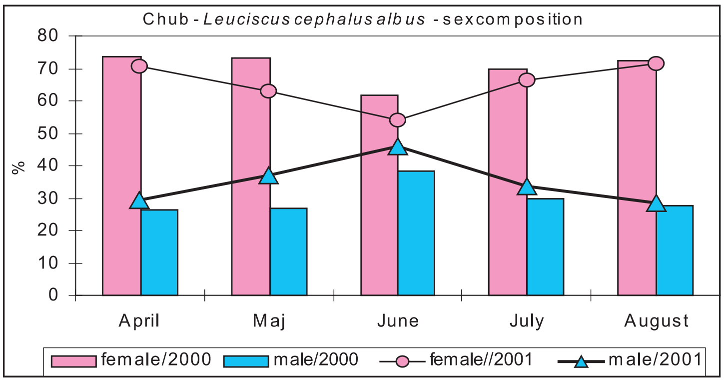

Figure 7. Monthly fluctuations of male and female individuals of chub *Leuciscus cephalus albus* in Lake Ohrid at the investigated sites in the course of 2000 and 2001

The sex composition of all the examined individuals in the course of the two investigated years points to a female dominance (Figure 8). This is to be expected having in mind the fact that almost always the number of females exceeds the number of caught male individuals during the period between spring and summer.

The growth of tourism, making new beaches and hotels, and the increasing use of boats that pollute the lake and disturb the tranquillity of the fish spawning sites have an immense adverse impact on the number of individuals that return to the former spawning sites, noting the fact that almost all cyprinids spawn at sites and periods when the number of tourists is the greatest.

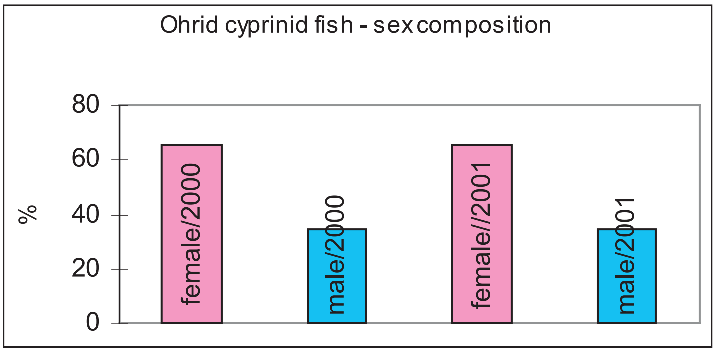

Figure 8. Sex composition of the experimental catches at the investigated sites in the course of 2000 and 2001

Evidenced macrophyte species serve as a habitat and food for a large number of organisms of the lake, and also as a breeding site for many species of fish. Lake Ohrid cyprinids are mainly phytophyllic species, in relation to the grounds where they lay their eggs. Any change in the qualitative and quantitative composition of the macrophyte vegetation inevitably causes a change in the spawning site. The spawning at the same site under the new conditions necessarily results in less efficient natural spawn (less hatched larvae, and with that less adult individuals).

In the course of 2000 and 2001, investigations of macrophyte vegetation were made at 13 sites from the eastern and south-eastern littoral of Lake Ohrid. In the investigated sites, 18 macrophyte species were determined (Table 1).

The anthropogenic pressure in respective parts of the lake provokes changes in the composition of the bottom and the quality of the water. As a result of such undesirable impact, new macrophyte associations started to occur, which – provided that they proceed with such intensity at certain sites (villages Trpejca and Pestani) – may result in a change of the species that spawn in those areas (salmonid spawning sites may convert into cyprinid species spawning sites).

Table 1. Survey of the macrophyte species in the investigated localities in the course of 2000 and 2001

Belt	I	II			III													
SPECIES / SITES	*Cladophora sp.*	*Phragmites communis* Trin.	*Scirpus lacustris* L.	*Typha latifolia* L.	*Potamogeton perfoliatus* L.	*Potamogeton lucens* L.	*Potamogeton crispus* L.	*Potamogeton pectinatus* L.	*Potamogeton acutifolius* Link.	*Zannichellia palustris* L.	*Myriophyllum spicatum* L.	*Myriophyllum verticillatum* L.	*Ceratophylllum demersum* L.	*Ceratophylllum submersum* L.	*Vallisneria spiralis* L.	*Elodea canadensis* Rich& Michx.	*Najas major* L.	*Najas minor* AL.
LJUBANISTA	+	+			+				+		+				+	+	+	
TRPEJCA	+										+	+						
GRADISTE	+	+			+			+		+	+					+		
ELESEC		+			+	+												
LAGADIN	+	+			+					+								
METROPOL	+	+			+					+								
GRANIT		+			+	+												
SILEKS	+	+			+	+				+							+	
MAZIJA	+	+			+	+	+	+		+	+		+		+			+
GRASNICA	+	+	+	+	+		+	+		+	+	+	+		+			
DALJAN	+	+		+	+		+	+		+	+		+	+	+		+	
ANDON DUKOV	+	+			+	+		+		+								
PODMOLJE	+	+	+	+	+					+								

Conclusions

From the performed investigations and previous long-term studies in this field, the obtained results may be summed up as follows:

- Material for investigation has been sampled for the following species: bleak *Alburnus alburnus alborella* Filippi, barbel *Barbus meridionalis petenyi* Heckel, grunec *Rutilus rubilio ochridanus* Karaman, Ohrid chub *Leuciscus cephalus albus* Bonaparte, Ohrid undermouth *Chondrostoma nasus ohridanus* Karaman, and moranec *Pachichylon pictum* Heck&Kner;
- At the investigated sites from the eastern and south-eastern littoral of Lake Ohrid (Ljubanista, Trpejca, Gradiste, Elesec, Lagadin, Metropol, Granit, Sileks, Mazija, Grasnica, Daljan, Andon Dukov and Podmolje), 18 macrophyte species were observed;
- From the recent studies, the condition of the fish populations can be described as good;
- In the sex composition, the number of females is significantly higher than the number of males. However, within the same population the number of individuals is almost the same;
- Due to the significant role of the spawning fish grounds in keeping optimum conditions (ambient equilibrium) for fish populations, it is necessary to continue these investigations in the following years. Both States that share Lake Ohrid must undertake certain measures for the protection of the spawning fish grounds against negative anthropogenic impact.

References

1. Jakovlevic, 1936. The macrophyte vegetation from Lake Ohrid, Archive of the Ministry of Agriculture. Belgrade. Year 3, volume 5, pp. 1-31.
2. Katanska, V. M., 1956. Methods for investigation of higher water plants in the fresh water live in the USSR. Vol. IV, pp. 160-183. Published by the Academy of Science of the USSR. Moscow and Leningrad.
3. Lind, O. T., 1979. Handbook of common methods in limnology. The C. V. Mosby Company, St. Luis – Toronto – London, 199 pp.
4. Naumoski, T., 1985. The oligomixis of Lake Ohrid. Hydrobiological Institute, Jubil. Issue, pp. 217-226 (in Macedonian with English summary).
5. Stankovic, S., 1960. The Balkan Lake Ohrid and its living world. Uitgeverij Dr. W. Junk. The Hague. Monogr. biol., 9, 357 pp.
6. Talevska, M., 1996. Biomass, production and main nutrients of the reed *Phragmites communis* TRIN. of Lake Ohrid. Master thesis, 122 pp.
7. Talevski, T., 1997. Investigation in gonads of moraneca *Pachichyilon pictus* from lake Ohrid. 6th Congress of Croatian biologists with international participation. Opatija, Croatia.
8. Talevski, T., 1998a. The influence of the selecitvity of the fishing nets upon the experimental fish catch structure of particular fishes from Lake Ohrid. First Congress of Ecologists of the former Yugoslav Republic of Macedonia with international participation, Ohrid.
9. Talevski, T., 1998b. The investigation population dynamic of grunec *Rutilus rubilio ohridanus* Kar. from Lake Ohrid. 2nd Congress of biologists of the former Yugoslav Republic of Macedonia with international participation, Ohrid.
10. Talevski, T., 2001. The investigation population dynamics of some fish species from Lake Ohrid. “Zasavica 2001”. Sremska Mitrovica. PMF, Novi Sad. Yugoslavia.

Phosphatase activity as an additional parameter for water assessments in the littoral region of Lake Ohrid

Angela Vasileska and Vera Novevska
Hydrobiological Institute, Ohrid, the former Yugoslav Republic of Macedonia

Introduction

Lake Ohrid is a transboundary lake, shared by Albania and the former Yugoslav Republic of Macedonia, with a surface area of 358.18 km^2, of which 119.39 km^2 belongs to Albania. Lake Ohrid is the biggest and the deepest lake in the Dassaret lake group of the Aegean lake zone with a maximum depth of 288.7 m.

The entire catchment area has a size of 664 km^2. There are some small and four bigger tributaries: rivers Sateska, Koselska and Velgoska in the former Yugoslav Republic of Macedonia and the river Cherava, shared by both countries (the upper part is on Albanian territory).

Long-term investigations of Lake Ohrid have shown that this aquatic ecosystem has an oligotrophic character. Eutrophication has occurred slowly, but currently the lake is under high anthropogenic impact. Two of the tributaries of Lake Ohrid (River Velgoska and River Cherava) are loaded with sewage, industrial waste water, and polluted water from rural areas.

Besides classical microbiological methods of water-quality assessments, new modern biochemical methods are also very important. These methods make it possible to roughly quantify transformed pollutants by the organothrophic component of the water microflora. One of those modern biochemical methods is the assessment of the water-environment activity as a result of the micro-heterotrophic activity, which controls the pathway of most organic components.

Phosphotases (enzymes that hydrolyze high-weight organic phosphorus compounds to orthophosphate) have essential functions in lake nutrient dynamics (Jansson et al., 1988) both in relation to the phosphorus cycle and carbon mobility in aquatic ecosystems. According to Hoppe (2000), phosphatase activity can manifest multiple functions in aquatic ecosystems related to phosphorus, available organic carbon and nitrogen. According to the mentioned author, this can be of special interest in substrate-depleted water ecosystems, where C-limitation can induce phosphatase activity.

Material and methods

The samples for microbiological investigations have been collected during the period November 2000-October 2001 from two sites in the littoral region of Lake Ohrid (River Velgoska and River Cherava) and from the littoral lake water where these two rivers flow into the lake.

The acid, neutral and alkaline phosphatase activity was estimated in the original water samples on p-nitrophenyl phosphate as a substrate. Except the phosphomonoesetase activity, the number of heterotrophic (saprophytic) bacteria (H) was determined on mesopepton agar as a medium, and the number of facultative oligotrophic bacteria (FO) on deluted mesopepton agar 1:10 (Petrovic et al., 1998). The ratio FO/H, which is a very good indicator for the conditions and the quality of the water in relation to its self-purification ability, was also estimated.

Results and discussion

The method of enzymatic activity estimates was for the first time applied to Lake Ohrid, and the acid, neutral and alkaline phosphatase activity was measured in the water of some sites in the littoral region of this lake.

A permanent high index of phosphatase activity was recorded in the water of the River Velgoska and in the littoral waters next to its inflow into the lake. These results are a small part of continued monitoring on this river, which indicate that this site is under unfavorable conditions. The alkaline phosphatase activity was permanently high in the water of River Velgoska, with an average activity of 5.15 $\mu mol/s/dm^3$, neutral phosphatase activity was temporally observed (1,95 $\mu mol/s/dm^3$), while the acid phosphatase activity was only incidentally observed in the water at this site (Figure 1).

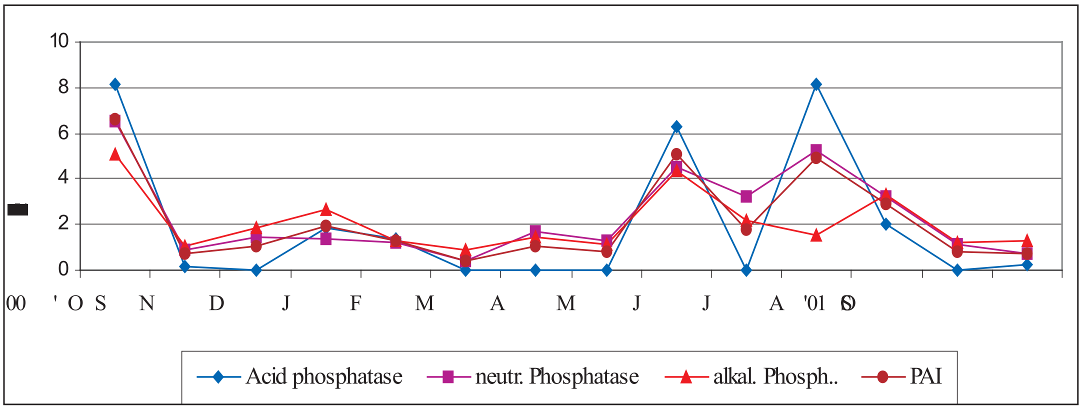

Figure 1. Dynamics of acid, neutral and alkaline phosphatase activities in the water of River Velgoska

The maximum activities of all phosphatases (acid, neutral and alkaline), recorded in August 2001, were probably generated by bacterial cells (their numbers were almost 120,000 bact/ml). This led to a decrease of the FO/H index (0.533). This biological reaction of the system was a result of an increasing content of dissolved organic matter in the water (26.04 mg/l) and also due to high temperature, a factor that is closely related to nutritional conditions in the ecosystem (Carlson and Caron, 2001).

The comparative activity analysis of the three phosphatase processes demonstrated that in littoral water (next to the inflow of the River Velgoska), the alkaline phosphatase activity was the most abundant with an average activity of 1.014 µmol/s/dm^3, neutral phosphatase had average activity of 0.792 µmol/s/dm^3, while acid phosphatase was incidentally present in the water with an average activity of 0.404 µmol/s/dm^3 (Figure 2).

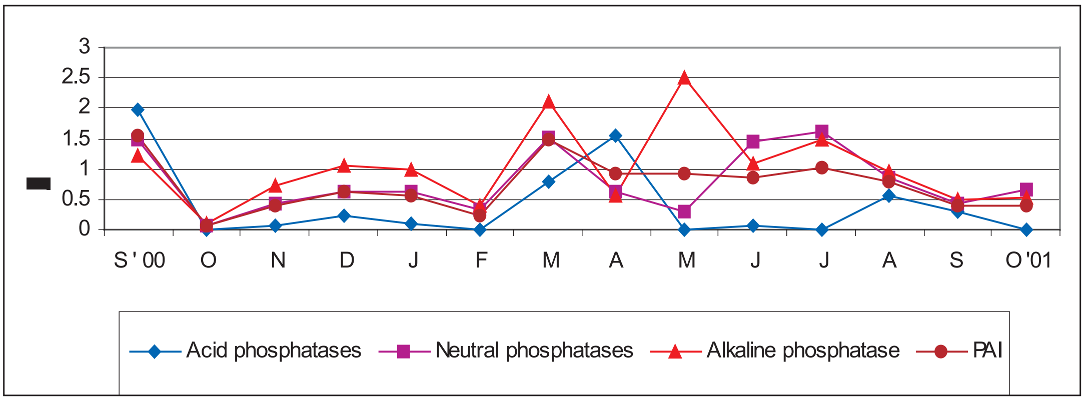

Figure 2. Dynamics of acid, neutral, alkaline phosphatase in the littoral water

The mentioned values for phosphatase activities are higher than activities measured in the littoral zone at another site, which once more indicate that this river has a strong negative influence on the littoral waters of Lake Ohrid. The results obtained by Lokoska (2000) for 1996-1998 demonstrated that the number of heterotrophic bacteria was permanently very high in the water of this river (almost 220,800 bact/ml). This tributary has a limited capacity for self-purification, because of the permanent input of industrial waste water, which contains inorganic and organic pollutants.

The average activities of the three phosphatase processes in the water of River Cherava were almost equal, since alkaline and neutral phosphatases were always active during our investigation (2.08 µmol/s/dm^3 and 2.15 µmol/s/dm^3, respectively), while acid phosphatase activities occurred occasionally, but they were high enough to result in an average activity of 2.02 µmol/s/dm^3 (Figure 3).

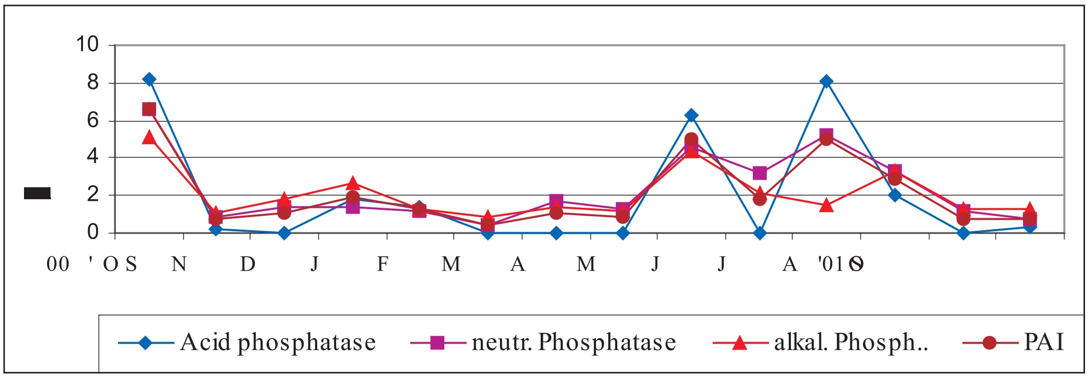

Figure 3. Dynamics of acid, neutral and alkaline phosphatase activities in the water of River Cherava

The maximum phosphatase activity of both river and littoral waters was recorded in September 2000. Acid phosphatase activities were 8.17 µmol/s/dm^3, neutral phosphatase 6.57 µmol/s/dm^3 and alkaline phosphatase activity 5.12 µmol/s/dm^3. The corresponding values for the littoral water were 2.676 µmol/s/dm^3, 1.061 µmol/s/dm^3 and 0.538 µmol/s/dm^3 (Figure 4). The high phosphatase activities were probably a result of the high content of dissolved organic matter present at that period (42.7 mg/l) in the water of River Cherava, and also as a result of tourist season, because the camp " Lubanista" is nearby.

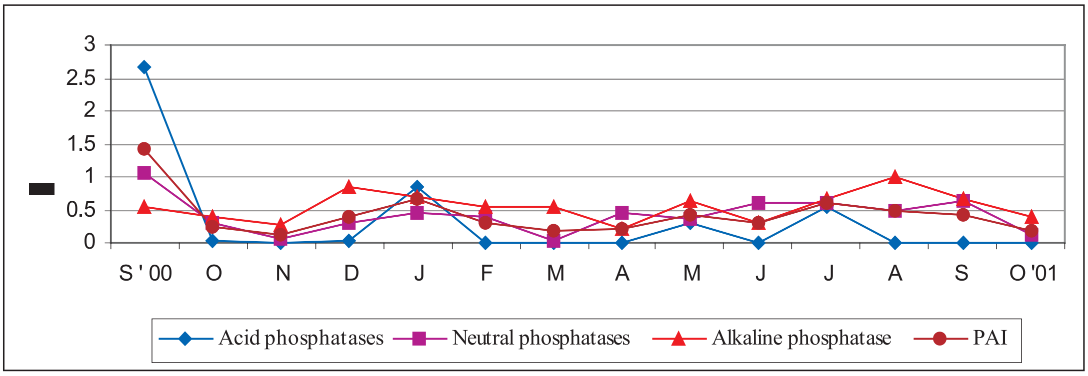

Figure 4. Dynamics of acid, neutral and alkaline phosphatases in the littoral water (inflow of River Cherava)

Conclusions

Acid, neutral and alkaline phosphatase activities were estimated in the water at four sites of Lake Ohrid during November 2000-October 2001.

The results demonstrated that the average activity in the water of the River Velgoska was 2.632 µmol/s/dm^3, which according to the proposed classification by Matavulj (1986) shows an average quality corresponding to the IIIa class, while the average value of PAI (phosphatase activity index) in the water of the River Cherava was 2.15 µmol/s/dm^3 (II-III class).

Average values of PAI in the littoral water were 0.429 µmol/s/dm^3 (inflow of River Cherava) and 0.707 µmol/s/dm^3 River Velgosca. This corresponds to class II according to Matavulj.

Comparative analysis of acid, neutral and alkaline phosphatase activities indicated that the highest activity was by alkaline phosphatase (permanently present in both in the littoral and river waters). Acid phosphatase took incidentally place in the water and was closely correlated with increasing dissolved organic matter content. The high concentration of organic substrates in the water has probably a stimulating effect on this kind of phosphatase.

Jansson et al. (1988) suggested that the conditions that are favorable for the acid phosphatase activity are not characteristic for most natural lakes. It is confirmed that bacteria and algae generally grow up better in alkaline environmental conditions, and they produce more alkaline than acid phosphatase.

References

1. Carlsson, P. and Caron, D. A., 2001. Seasonal variation of phosphorus limitation of bacterial growth in a small lake. Limol. Oceanogr. 46(1), pp. 108-120.
2. Hoppe, H. G., 2000. Phosphatase Activity in the Sea. In: B. A. Whitton, I. Hernandez (eds.): Phosphatase in the environment. Kluve Academic Publishers. Dordrecht, pp. 1-22.
3. Jansson, M., Olsson, H., Pettersson. K., 1988. Phosphatases: origin, characteristics and function in lakes. Hydrobiologia. 170, pp. 157-175.
4. Lokoska, L., 2000. Vlijanieto na vodata od pritokite vrz kvalitativniot sostav na bakterioplanktonot vo Ohridskoto Ezero. Doktorska disertacija, Institut za Biologija, Skopje, 206 pp.
5. Matavulj, M., 1986. PhD thesis. Faculty of Natural Sciences and Mathematics. University of Zagreb.
6. Petrovic O., Gajin S., Petrovic O., Matavulj M., Radnovic D., Svirev Z., 1998. Microbiological water-quality tests. Biological Institute. Novi Sad, 108 pp.

A new approach to estimate eutrophication: results from the EU-project SIGNAL

Maren Voss
Baltic Sea Research Institute, Seestr. 15, 18119 Rostock, Germany
Marianna Pastuszak
Sea Fisheries Institute, Kollatahja 1, 81-332 Gdynia, Poland
Stanislaw Sitek
Sea Fisheries Institute, Pl Slowianski 11, 72-600 Swinoujscie, Poland
Constanze Stegemann
University of Bochum, Universitätsstr. 150, 44780 Bochum, Germany

Introduction

Globally, anthropogenic impact on the nitrogen balance via fertiliser production, fossil fuel combustion and leguminous crops is larger than natural nitrogen sources. For the Baltic Sea, this budget is probably even more shifted towards the domination by human nitrogen input. This is mainly delivered by major rivers that carry a total of 700, 000 tons N/year into the Baltic Sea. The most important ones are the Daugava (29,000 t N-NO_3^-/year), the Vistula (60,000 t N-NO_3^-/year), the Neva (22,000 t N-NO_3^-/year), and the Oder (42,000 t N-NO_3^-/year) rivers (Stalnacke, 1996).

Stable isotope data in nitrogen compounds are increasingly used to detect and to follow the anthropogenic input of nutrients (Cabana and Rasmussen, 1996; McClelland and Valiela, 1998). Carbon, nitrogen and oxygen compounds contain naturally a small amount of the heavy isotope, 0.1% ^{13}C, 0.4% ^{15}N, and 0.2% ^{18}O, that can be measured with great precision in isotope ratio mass spectrometers. Numbers are given in ‰ according to the formula:

$$\delta^{15}N[‰] = \left(\frac{\left(\frac{^{15}N}{^{14}N}\right)_{Probe}}{\left(\frac{^{15}N}{^{14}N}\right)_{Referenz}} - 1 \right) * 1000$$

The reference gas has a known isotope ratio and is calibrated against international standards. For nitrogen the standard is air, for carbon, the carbonate from a belemnite from the PeeDee formation, and for oxygen, standard mean ocean water, SMOW.

Terrestrial and freshwater systems have $\delta^{15}N$ values in the range of 3.9±3.1‰ and 4.3±2.7‰, respectively, while marine waters are more enriched with 7.2±2.6‰ (Owens, 1987). This patterns leads to an enrichment in $\delta^{15}N$ in particulate organic nitrogen (PON) in estuaries with increasing salinities. However, in recent years, a change of this patterns was described for estuaries with high loads of anthropogenic nutrients (Voss and Struck, 1997). Nutrient rich waters seem to carry higher isotope signals than pristine waters and even marine ones thus turning the natural gradient into its opposite (Voss et al., 2000). Isotope values of over 12‰ were found in surface sediments of the Oder lagoon representing the mean ^{15}N-signal of the input over the last decade. Direct evidence for the relationship of high $\delta^{15}N$ values and high N-input from certain sources was presented by McClelland et al. (1997). They found a significant relationship between groundwater N from sewage and the isotopic composition. However, no relationship between fertilizer N-input and the stable isotopes could be established.

Not only the stable nitrogen isotopes but also the oxygen isotopes in nitrate can be used to study input pathways and sources as Amberger and Schmidt (1987) showed in their pioneering study on nitrate in different wells and fertilisers. They suggested using both markers to find certain eutrophication sources for groundwater. New techniques for the extraction of nitrate lead to a wider application of this approach (Chang et al., 1999; Silva et al., 2000) and an ongoing study shows high $\delta^{18}O$ values in sewage-contaminated German rivers. In the SIGNAL project, both tracers are used to describe nutrients loads from rivers and their possible input sources.

Cyanobacteria blooms that regularly occur in the Baltic Proper, due to an excess supply of phosphate, are another large N-source of the Baltic Sea. Over the last few years, increasing amounts of fixed nitrogen have been estimated and nowadays a number of 370.000 t N per year is suggested. Isotopic tracers also mark this N-input since the cyanobacteria do not rely on reduced nitrogen forms but fix dissolved dinitrogen from the water with a $\delta^{15}N$ value around 0‰. Therefore, this group of phytoplankton is clearly marked with low $\delta^{15}N$ values compared to other phytoplankton with higher values by 5-6‰ (Carpenter et al., 1997).

Carbon cycling is mainly driven by the exchange between the atmosphere and the ocean. Stable isotopes values of organic and inorganic carbon are fundamentally different in fresh versus marine waters. Since the inorganic carbon dissolved in water is heavier in $\delta^{13}C$ than in air, marine particulate organic matter is also isotopically heavier than terrestrial organic matter (Peterson and Fry, 1987). Photosynthesis discriminates against $\delta^{13}C$ with over 20‰. If, however, the DIC (dissolved inorganic carbon) becomes a limiting resource, fractionation during photosynthesis decreases and $\delta^{13}C$ values increase. Higher $\delta^{13}C$ - particulate organic carbon in eutrophied waters were thus explained by reduced fractionation due to high growth rates.

All three isotopic markers are used in the SIGNAL project to follow and understand matter cycling at the river mouth and in river plumes. The potential, which the above-described markers have for the study of human impact in costal areas and the Baltic Sea as a whole, will be tested during the project. In the end, a budget will assess the impact of the additional nitrogen for matter cycling. This paper describes first results from four selected rivers and combines land use patterns and input sources with the isotopic signatures in river nitrate and PON.

Discussion

Different sources for river nitrate and biological processes transforming the stable isotope ratios along the river have to be considered to understand the signals found. There is evidence from first preliminary data for different source isotope signals when correlated with the vegetation in the drainage area (Figure 1). Nitrate-and PON-$\delta^{15}N$ in the river were higher when agricultural fields dominated in the drainage area. Industrial fertiliser probably serves as the dominating N-source. It is generally assumed to have isotope ratios close to 0‰ due to its way of manufacturing from atmospheric nitrogen. Manure, a fertiliser from pig and cattle raising, has $\delta^{15}N$ values of up to 20‰ or higher (Heaton, 1986). Nevertheless, both N-sources cannot easily be differentiated after their transfer through the soil. Soil processes, like degradation, nitrification and denitrification, transform the isotope values and lead to an overall increase in $\delta^{15}N$ (Nadelhoffer and Fry, 1994). Over-fertilised fields export nitrate no matter what the source was and carry elevated $\delta^{15}N$ values of 6-9‰. Sewage from waste-water treatment plants is another source of high $\delta^{15}N$ values. All these sources are man-made. In the Baltic Sea drainage area, we assume the largest N-source is from farmland and not sewage from treatment plants (point sources), since the diffuse input from land is considered to deliver the largest share of nitrogen (HELCOM, 1993). Additionally highest flow co-occurs with highest nitrate concentrations in river water which is rather typical for streams receiving their loads in spring during snow melt and at times of low plant growth. It is concluded that $\delta^{15}N$ -NO_3^- and PON values of 8‰ and higher indicate nitrogen sources from farming under excess fertiliser use. The more pristine environment co-occurs with low stable nitrogen isotope values.

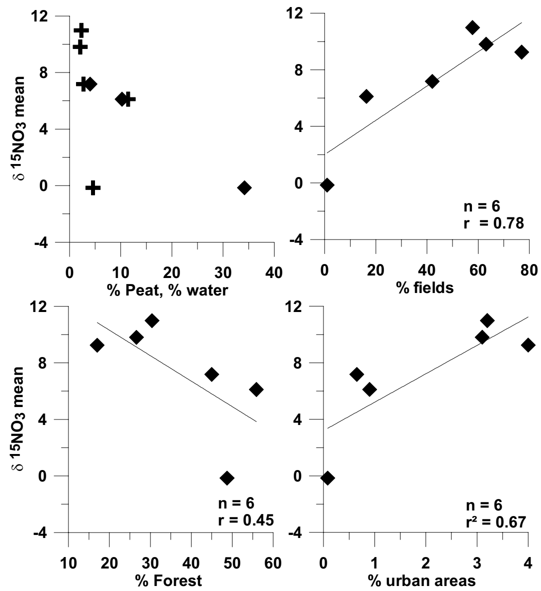

Figure 1. Land use in the drainage areas vs. stable nitrogen isotopes in nitrate at the river mouth

Turnover of nitrogen changes the isotope values considerably and $\delta^{15}N$ of nitrate and ammonia has been used to identify estuarine processes (Horrigan et al., 1990). Although this aspect of internal cycling is less important in this study, we clearly see that both stable isotopes in nitrate have similar patters. In winter the $\delta^{15}N$ and $\delta^{18}O$ values decrease – most probably due to nitrification, when the oxygen comes from water and dissolved oxygen (Kendall and McDonell, 1998). The ammonia concentration decrease while the isotope values increase at the same time. During the cruise, another process could be followed which was the nitrate uptake and fractionation of phytoplankton. Nitrate was elevated in part of the investigation area where the development of an eddy was observed. This nitrate was presumably consumed by phytoplankton. The PON might be generated through growth or it was imported with the water from the Vistula River. Since the isotope values of the Vistula River PON of 4-5‰ are typical in winter, the PON sampled resembles the river signal. On the other hand, biological processes like degradation increase the $\delta^{15}N$ (Owens, 1985). Our signal found in the Bay of Gdansk can therefore be generated either by mixing of the Vistula River with Baltic Sea waters or it can originate from phytoplankton growth and degradation processes.

Lagoon processes like turnover and transformation of nutrients is another piece of coastal nutrient dynamics that is being investigated in the SIGNAL project. Nutrients are heavily reduced in the Oder lagoon as our data from the station Widuchowa compared with the Swina outlet show. Both stations are roughly 100 km apart and it takes days for the water to travel from one station to the next. Additionally, the lagoon waters have variable residence times of days to weeks – long in summer and autumn and short in spring. This allows a number of biological processes to reduce or release nutrients (Humborg et al., 2000). Taking uptake and fractionation of nitrate between the stations in the Oder River and the Swina canal into consideration, we calculated the presumed $\delta^{15}N$ - NO_3^- values for the Swina station. Those were much higher than the $\delta^{15}N$ values measured in the Swina canal. This means that all the nitrate missing was used up without the usual fractionation processes. Nevertheless, the role of the lagoon consists in a substantial reduction of nutrient concentration.

References

1. Amberger, A. and Schmidt, H.-L., 1987. Natürliche Isotopengehalte von Nitrat als Indikatoren für dessen Herkunft. Geochimica et Cosmochimica Acta 51, pp. 2699-2705.
2. Cabana, G. and Rasmussen, J. B., 1996. Comparison of aquatic food chains using nitrogen isotopes. Proc. Natl. Acad. Sci. USA 93, pp. 10844-10847.
3. Carpenter, E. J., Harvey, H. R., Fry, B. and Capone, D. G., 1997. Biogeochemical tracers of the marine cyanobacterium Trichodesmium. Deep-Sea Research I 44(1), pp. 27-38.

4. Chang, C. C. Y., Langston, J., Riggs, M., Campbell, D. H., Silva, S. R. and Kendall, C., 1999. A method for nitrate collection for d15N and d18O analysis from waters with low nitrate concentrations. Can. J. Fish. Aquat. Sci. 56, pp. 1856-1864.
5. Heaton, T. H. E., 1986. Isotopic studies of nitrogen pollution in the hydrosphere and atmosphere: A review. Chemical Geology, pp. 87-102.
6. HELCOM, 1993. Second Baltic Sea Pollution Load Compilation. Baltic Sea Environ. Proc. No. 45.
7. Horrigan, S. G., Montoya, J. P., Nevins, J. L. and McCarthy, J. J., 1990. Natural isotopic composition of dissolved inorganic nitrogen in the Chesapeak Bay. Estuarine, Coastal and Shelf Science 31, pp. 393-410.
8. Humborg, C., Fennel, K., Pastuszak, M. and Fennel, W., 2000. A box model approach for a long-term assessment of estuarine eutrophication, Szczecinski Lagoon, southern Baltic. Journal of Marine Systems 25, pp. 387-403.
9. Kendall, C. and McDonell, J. J., 1998. Isotope Tracers in catchment hydology. Elsevier.
10. McClelland, J. W. and Valiela, I., 1998. Changes in food web structure under the influence of increased anthropogenic nitrogen inputs to estuaries. Marine Ecology Progress Series 168, pp. 259-271.
11. McClelland, J. W., Valiela, I. and Michener, R. H., 1997. Nitrogen-stable isotope signatures in estuarine food webs: A record of increasing urbanization in coastal watersheds. Limnology and Oceanography 42(5), pp. 930-937.
12. Nadelhoffer, K. J. and Fry, B., 1994. Nitrogen isotope studies in forest ecosystems. In Stable isotopes in Ecology and Environmental Science (ed. K. Lajtha and R. H. Michener), pp. 22-44. Blackwell Scientific Publications.
13. Owens, N. J. P., 1985. Variations in the natural abundance of 15N in estuarine suspended particulate matter: A specific indicator of biological processing. Estuarine, Coastal and Shelf Science 20, pp. 505-510.
14. Owens, N. J. P., 1987. Natural Variation in 15N in the Marine Environment. Advances in Marine Biology 24, pp. 389-451.
15. Peterson, B. J. and Fry, B., 1987. Stable isotopes in ecosystem studies. Annual Review Ecol. Syst. 18, pp. 293-320.
16. Silva, S. R., Kendall, C., Wilkison, D. H., Ziegler, A. C., Chang, C. C. Y. and Avanzino, R. J., 2000. A new method for collection of nitrate from fresh water and analysis of nitrogen and oxygen isotope ratios. Journal of Hydrology 228, pp. 22-36.
17. Stalnacke, P., 1996. Nutrient loads to the Baltic Sea. cumulative.
18. Voss, M., Larsen, B., Leivuori, M. and Vallius, H., 2000. Stable isotope signals of eutrophication in coastal Baltic Sea sediments. Journal of Marine Systems (Special Issue) 25, pp. 287-298.
19. Voss, M. and Struck, U., 1997. Transport of particulate organic substances from the Odra River into the Baltic Sea traced by stable nitrogen isotopes. Marine Chemistry 59, pp. 35-49.

Impact of the Oder River nutrient load reductions on the trophic state of the Szczecinski Lagoon: a modelling approach

Magdalena Wielgat and Gerald Schernewski
Baltic Sea Research Institute Warnemünde (Institut für Ostseeforschung Warnemünde)

Introduction

The Oder River, on the border of Germany and Poland, with an average flow of 550 m^3/s, is the fifth largest river entering the Baltic Sea. Its large drainage area (120.000 km², with about 13 millions inhabitants) belongs to the most densely populated as well as industrialized areas of the Baltic Sea catchments. The Oder River carries large nutrient loads. According to Behrendt et al. (2001), the average annual riverine load of nutrients discharged by the Oder River is 12,840 t of phosphorus and 124,250 t of nitrogen (average of 1993-1997) and the river contributes about 9% to the total load into the Baltic Sea.

The Oder River estuary consists of many river branches, a lake and finally the large (680 km²) and shallow Szczecinski Lagoon, with an average depth of 3.8 m. With an average water residence time of about 2 months, the riverine waters have pronounced impact on the trophic state of the Szczecinski Lagoon, contributing to eutrophication and low water transparency (often below 1 m depth).

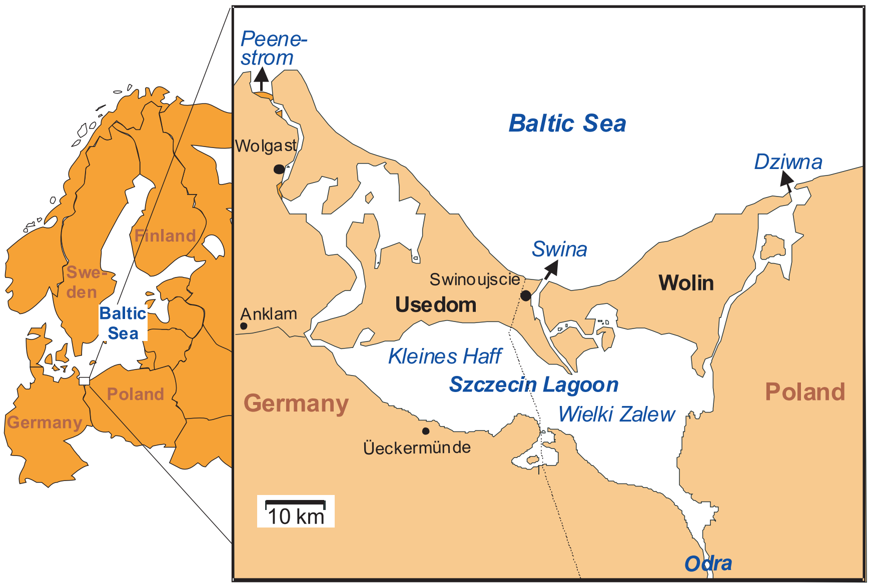

Figure 1. Szczecinski Lagoon, the final part of the Oder River estuary

At the same time, summer tourism is the most important economic factor in this region (Schernewski and Sterr in press). Ongoing growth of tourist industry is regarded as an important possibility to fight the economic problems both on the German and the Polish side. Especially for the towns and villages located in the inner part of the Oder estuary, along the Szczecinski Lagoon coast, water quality problems are, or at least can be, obstacles for economic development. Intensive algal blooms are common in the Szczecinski Lagoon. During summer, algal blooms often form thick green layers as well as foam on the water surface. More problematic than these nuisances is the potential toxicity of many cyanobacteria. Intoxication of animals has been reported in inner coastal waters several times, and beach closings and bathing prohibitions are known consequences of these algal blooms. Most important measures to decrease phytoplankton blooms are reductions of the nutrient input from the river catchments.

The 50% Helsinki Commission (HELCOM) nutrient load reduction: state and perspective

During the past two decades many international Baltic wide initiatives were launched in order to enforce reduction of phosphorus and nitrogen loads discharged to the Baltic Sea and its coastal water bodies. The most important initiative was undertaken in 1988 by the Ministers of environmental protection of all Baltic Sea countries. It was agreed within the 1988 Ministerial Declaration that every country would reduce its loads by 50% as compared to the year 1985. Evaluation of nutrient load reduction revealed large regional differences (Lääne et al., 2002). Regarding point sources, the 50% phosphorus reduction between the mid-1980s and 1995 was achieved by nearly all Baltic Sea countries, and the phosphorus loads altogether decreased by 39%. With respect to nitrogen from point sources, most countries failed and a total reduction by 30% can be assumed. A 50% reduction of the diffuse loads was met only by a few states.

About 90% of the Oder catchment is located within the Polish territory. The evaluation report reveals that Poland did not meet the 50% reduction goal (Jarosinski, 2002). The point sources loads of phosphorus and nitrogen were reduced in Poland only by 23% and 24% and from diffuse sources by 30% and 10%. In the Oder catchment, about 62% of the phosphorus load but only about 37% of the nitrogen load have their origin in point sources (Behrendt, 2001). To reduce the nutrient load from diffuse sources is a problematic and long-term task. Large amounts of phosphorus are bound in the uppermost soil layer and subject to steady erosion. Due to ongoing land use, nitrogen has reached high concentrations in the groundwater and is stored there for years and even decades. The long retention time of these nutrient sources prevent a fast reduction of the riverine loads. Therefore the intended 50% reduction of the nutrient loads might take another decade.

In this paper we present an application of an ecological model of the Szczecinski Lagoon. Our aim is to simulate and analyse the possible effects of the 50% nutrient load reduction on phytoplankton growth and the trophic state in the Szczecinski Lagoon.

The ecological model of the Szczecinski Lagoon

The dynamic box model consists of two boxes representing two parts of the lagoon Great Lagoon and Small Lagoon side, because they differ in water retention time. The model consists of the following state variables: DIN, PO4, nitrogen and phosphorus in detritus (suspended organic matter), nitrogen and phosphorus in the sediment and one phytoplankton group. The model covers the dominant internal nutrient transformation processes: nutrient uptake by phytoplankton, mineralization of nutrients, sedimentation, denitrification of nitrogen from water and sediment as well as burial of nutrients in sediment. All processes are described on the basis of existing knowledge on nutrient cycling and phytoplankton growth in the brackish water ecosystems, inter alia, the work by Savchuk and Wulff (1996). Zooplankton was considered to be of minor importance in the lagoon nutrient cycling and is not represented in the model state variables. The model is driven by external forces such as the seasonal changes of light and temperature, the nutrient loads discharged with the Oder River and from the immediate lagoon drainage area. At present stage, the model does not take into account inflows of Baltic Sea water. The internal time scale of the model is one day. The model was calibrated against data obtained from the regular monitoring programmes carried out in Great Lagoon by the Westpomeranian Inspectorate of Environmental Protection (WIOS in Szczecin) and in the Small Lagoon by the Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern.

Nutrient load reduction simulations

A seven-year simulation of phytoplankton growth in the Great Lagoon was carried out for the period 1990-1997 to validate the model. The simulated phytoplankton concentrations, indicated by Chlorophyll a concentrations, are in agreement with the measured values. The model indicates that in the 1990s the phytoplankton growth was not controlled by nutrients despite some reduction in pollution load carried out by the Oder River in the 1990s (Figure 2). Light availability remained the main factor controlling phytoplankton growth.

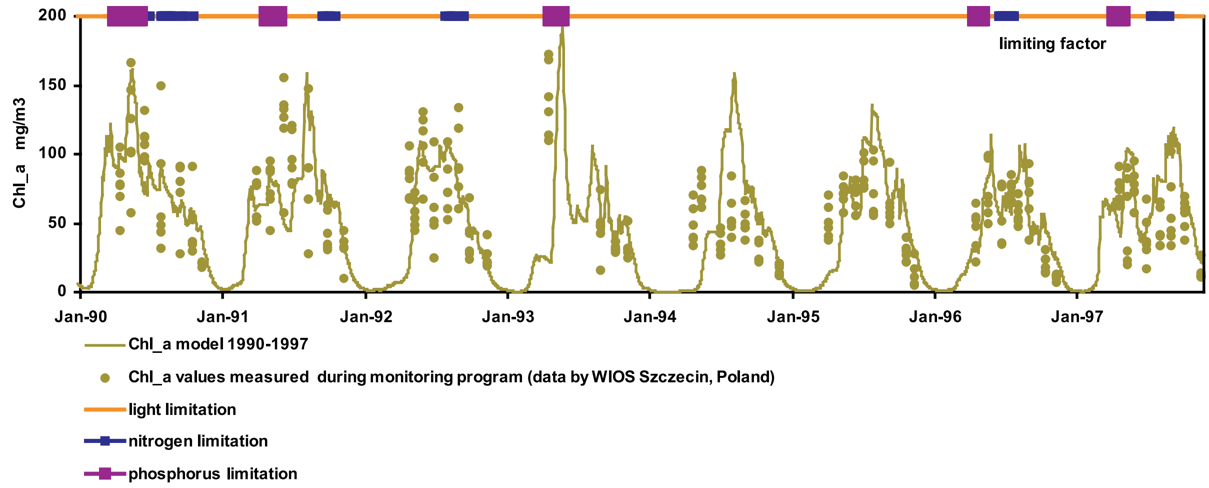

Figure 2. Simulated phytoplankton growth in the Great Lagoon as compared to measured data for the 1990-1997 period (the upper line indicates limiting factor)

The second simulation covers the period 1982-1989. These years are the basis of the 50% nutrient load reduction suggested by Ministerial Declaration and HELCOM. The simulation takes into account measured values for water discharge data of 1982-1989, but the Oder River load with respect to nitrogen and phosphorus was reduced by 50%. The model results (Figure 3) suggest that the nutrient load reduction suppresses the algal growth. After a 50% reduction of the riverine load, phosphorus and nitrogen become limiting elements for phytoplankton growth. Due to the lack of external nutrient input, the phytoplankton growth is based mainly on nutrients recycled within the system.

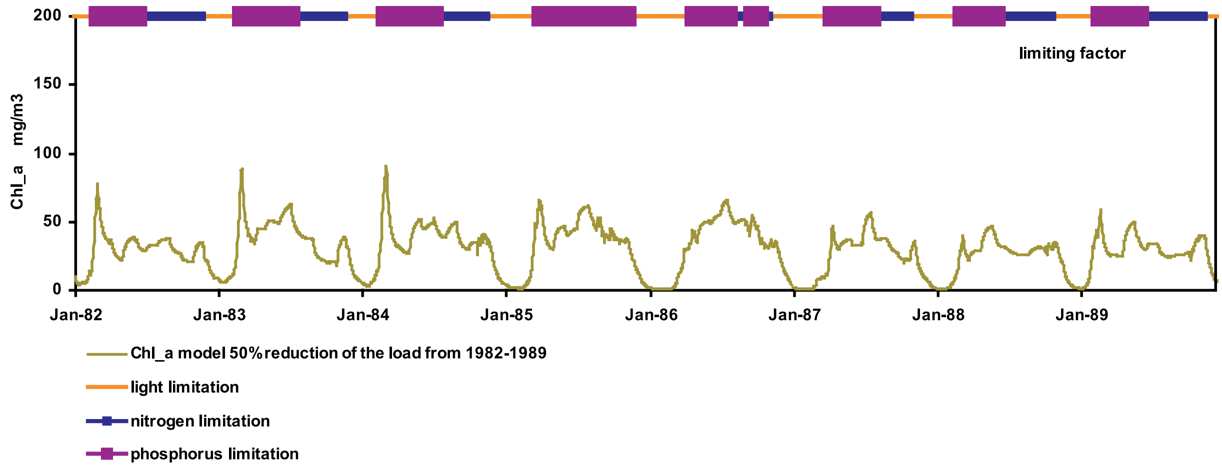

Figure 3. Simulated phytoplankton growth in the Great Lagoon with the Oder River phosphorus and nitrogen loads for the period 1982-1989 reduced by 50% (the upper line indicates limiting factor)

Discussion

The model gives some indications on the possible reaction of a water body system to management measures undertaken within its drainage area. Even with a relatively simple box model it is possible to obtain some insight on the basic internal processes governing the phytoplankton growth (Schernewski and Wielgat, 2001), such as factors controlling phytoplankton growth, and observe changes of these factors following changes forcing functions of the model (e.g. external loads of nutrients). Such insight might be an indication of what management measures are needed. However, due to the simple structure of the model and uncertainties connected to complex and altering biological systems the results have to be treated carefully.

An example presented here explains how a limitation factor might be crucial to understand impact of the reduced nutrient loads on phytoplankton density and algal blooms. The external nutrient sources influence on the phytoplankton growth (primary production) versus internal cycling can be shown by the model and also later calculated from its nutrient fluxes. Estuaries and coastal regions contribute large portion of the “new” primary production (i.e. production based on nutrients originating from allochthonous (external) sources) but, on the other hand in a shallow well mixed water body, chemical and biological processes favour substantial nutrient recycling.

It is well known and supported by our results, that nutrient load reduction in the catchment are not only a suitable measure, but the only sustainable measure to reduce water quality problems in the coastal lagoon. Despite the observed reduction of phytoplankton after the nutrient reduction, the absolute Chlorophyll a concentrations remain very high and will keep the lagoon in an eutrophic state.

References

1. Behrendt, H., Dannowski, R., Deumlich, D., Dolezal, F., Kajewski, I., Kornmilch, M., Korol, R., Mioduszewski, W., Opitz, D., Steidl, J. and Stronska, M., 2001. Point and diffuse emissions of pollutants, their retention in the river system of the Oder and scenario calculations on possible changes. UBA Research Report, Project 298 28 299, 271 pp.
2. Jarosinski, W., 2002. Polish national report on nutrient loads. In : Lääne, A. et al.: Evaluation of the implementation of the 1988 Ministerial Declaration regarding nutrient load reductions in the Baltic Sea catment area. The Finnish Environment, 524, Helsinki, pp. 153-167.
3. Lääne, A., Pitkänen, H., Arheimer, B., Behrendt, H., Jarosinski, W., Lucane, S., Pachel, K., Räike, A, Shekhovtsov, A., Svendsen, L. and Valatka, S., 2002. Evaluation of the implementation of the 1988 Ministerial Declaration regarding nutrient load reductions in the Baltic Sea catchment area. The Finnish Environment, 524, Helsinki, 195 pp.
4. Savchuk, O. and Wulff, F., 1996. Biogeochemical transformations of nitrogen and phosphorus in the marine environment – Coupling Hydrodynamic and Biogeochemical Processes in Models for the Baltic Proper. Systems Ecology Contributions No. 2, Stockholm, 79 pp.
5. Schernewski, G. and Wielgat, M., 2001. Eutrophication of the shallow Szczecinski Lagoon (Baltic Sea): modelling, management and the impact of weather. In: Brebbia, C.A. (ed.): Coastal Engineering: Computer Modelling of Seas and Coastal Regions. Witpress, Southampton, pp. 87-98.
6. Schernewski, G. and Sterr, H. (in press). Tourism and environment quality at the German Baltic coast: conflict or chance? In: Schernewski and Schiewer (eds.): Baltic Coastal Ecosystems: Structure, Function and Coastal Zone Management. CEEDES-Series, Springer Verlag.

Organic pollution in the Oder River

Lidia Wolska and Jacek Namieśnik
Gdańsk University of Technology, Chemical Faculty, Gdańsk, Poland

Introduction

The Oder is the second biggest river in Poland. In its upper course, the Oder flows through the most industrialized and urbanized areas of Poland. The areas around the middle and lower course are mainly agricultural with the highest agrarian production. These activities have a negative effect on the ecosystem of the Oder basin (e.g. quality of surface waters used as a source of drinking water).

The present investigations were carried out within the frame of the International Oder Project (IOP). The analytical part of this project (concerning interdisciplinary studies of the Oder basin) includes the determination of various groups of organic and inorganic compounds in water and in sediments.

Studies performed by Gdańsk University of Technology focused particularly on organic compounds in aqueous and soil samples, including compounds belonging to different classes:

- Volatile organic compounds (VOCs);
- Polycyclic aromatic hydrocarbons (PAHs);
- Polychlorinated biphenyls (PCBs);
- Chlorobenzenes (CB); and
- Pesticides.

Six sampling campaigns were organized in the period from August 1997 to May 2000, one directly after the flood in 1997.

Results

Water

During the study period, PAH pollution of the Oder water did generally not exceed allowable levels, and was therefore not critical (the total content of 16 PAHs ranged from below the detection limit of 1 ng/l to 1.5 µg/l). Higher concentrations of PAHs were found in the upper course of the Oder River.

PCBs were detected in water samples from the whole Oder basin at concentration levels below 10 ng/l and quite often even below the detection limit of 1 ng/l.

The concentration of organic sulphur compounds during the entire sampling period varied from the detection limit to about 2 µg/l.

Aliphatic and aromatic hydrocarbons were only occasionally detected in water samples at concentrations below 10 µg/l.

The highest concentration of chloroorganic compounds (ca. 835 µg/l) was found in Brzeg Dolny in August 1997. From this particular site, concentrations slowly decreased along the course of the river reaching several µg/l 300 km downstream.

Volatile organic compounds are shown in Figure 1.

The concentrations of pesticides in water are generally lower, or much lower, than the Polish standards for sewage, surface water and for tap water.

Sediment

Polycyclic aromatic hydrocarbons in sediment

The pollution of sediments with polycyclic aromatic hydrocarbons (PAHs) in the Oder catchment area ranged from below the detection limit of 1 µg/kg to ca. 50 mg/kg. In general, the differences in concentration among different sampling periods were not high. A comparison of the data from different areas indicated that the pollution with PAHs is much higher in the upper course of the Oder River. According to the Polish recommendations, a soil with such PAHs concentrations as found in quite many samples in this study is regarded as polluted or strongly polluted.

Polychlorinated biphenyls in sediment

The content of PCBs was below 20 µg/kg, and often even below 10 µg/kg which are considered low values. As a rule, the higher concentrations were observed in the region where pulp and paper industry is situated.

In Poland, the total PCBs maximum allowable concentration (MAC) for sediments has not been established yet, but in the developed countries MAC is set at the level of 100 µg/kg. According to European standards the studied sediments can be regarded as non-polluted.

Volatile organic compounds in sediment

- Volatile organic sulphur compounds (VOS). Organic sulphur compounds in the sediment samples were present at higher levels than in water samples, especially in the upper course of the river. The concentrations ranged from the detection limit to ca. 60 µg/kg. It was assumed that, as in the case of water samples, the pollution with VOSs might have originated from human activities, but the natural processes were its main source;
- Aliphatic and aromatic hydrocarbons. In sediments, specifically in supernatant water, aliphatic and aromatic hydrocarbons were detected at higher level than in water, but generally their concentrations did not exceed 70 µg/l. The only exception was the occurrence of toluene in supernatant water at a relatively high concentration, above 20 µg/l, in samples from the vicinity of Chałupki, a site close to the Polish-Czech border. This phenomenon was observed for each sampling period. The fact that toluene occured only in sediments suggests that it might be a biodegradation product of other anthropogenic organic pollutants;
- Chloroorganic compounds (VOCl). The concentration of chloroorganic compounds in sediments was about 100 times lower as compared to the concentrations in water. The highest concentrations of about 2 µg/l were found in the upper course of the Oder River.

Chlorobenzenes in sediment

The concentration of chlorobenzenes in sediments was considerably higher in comparison to water samples, ranging from the detection limit to ca. 750 µg/kg at Brzeg Dolny in May 2000.

The increased concentration of chlorobenzenes in sediments was observed in the same regions of the Oder River as for water samples, i.e. in sediment samples at the source of the Oder River (values from 150 to 650 µg/kg), in samples from Brzeg Dolny and at sampling sites downstream of Brzeg Dolny, and also in the Szczecinski Lagoon (values from ca. 100 to about 400 µg/kg).

The results confirmed the conclusions previously drawn for water samples. The same sources are responsible for pollution in the above mentioned parts of the Oder River, i.e. releases from transboundary sources in the Czech Republic, the chemical plant at Brzeg Dolny and ships in the Szczecin harbour.

Pesticides in sediment

The concentrations of pesticides in sediments were much lower than the proposed Dutch standards of 2-6 mg/kg dry weight of soil. The total concentration of the nitrogen/phosphorus containing pesticides in sediments varied from 0 to 132 µg/kg and for organochlorine pesticides from 0 to 33 µg/ kg.

The highest concentrations of individual pesticides were found in the region of Szczecin and in the Szczecinski Lagoon (approximately 30 µg/kg in the Pomeranian Bay I, and about 26 µg/kg in Świna near Świnoujście, in May 1998) and indicate that this area is the most polluted one.

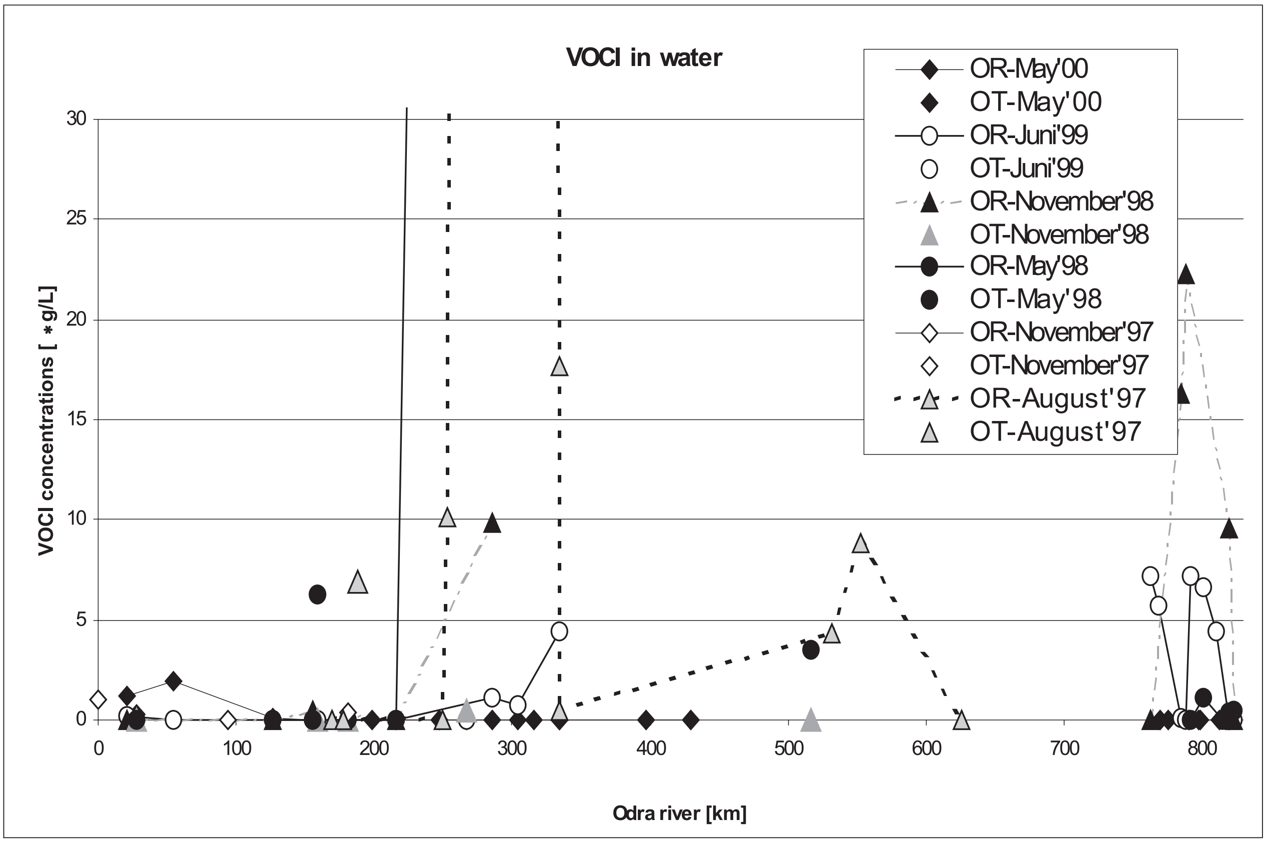

Figure 1. Volatile organic hydrocarbons concentrations along the course of the Oder River and its tributaries

Conclusions

Taking into account the data from all the sampling campaigns, it can be concluded that the water pollution of the Oder and its tributaries with PCBs and pesticides is negligible.

PAH pollution of Oder water did not exceed maximum permitted levels and was therefore not critical.

The highest concentration of volatile chloroorganic compounds and chlorobenzenes in water were found in Brzeg Dolny. From this site, the concentration slowly decreased along the course of the river. In Brzeg Dolny is located the Chemical Plant "Rokita", which was on the list of 80 plants of highest environmental pollution in Poland.

Exceptionally high concentrations of tetrachloroethene were determined in the Szczecinski Lagoon. This can be regarded as incidental pollution probably caused by leakage from tankers.

Significant sediment pollution with PAH in the upper course of the Oder is an environmental pollution problem.

Acknowledgements

This study was done in the framework of the International Oder Project (IOP). The financial support by the German Federal Ministry of Education and Research and by the Foundation of Polish-German Cooperation is gratefully acknowledged.

Competition of interests in the Niger River basin (Mali)

Leo Zwarts [1]
Institute for Inland Water Management and Waste Water Treatment (RIZA), Smedinghuis, Zuiderwagenplein 2, 8224 AD Lelystad, P.O. Box 17, 8200 AA Lelystad, The Netherlands
e-mail: l.zwarts@riza.rws.venw.nl, web site: http://www.riza.nl/index.html

The Inner Delta of the Niger River in Mali is one of the largest riverine floodplains of the world. Since the area is situated on the southern edge of the Sahara, where the local rainfall is limited, the flooding of this wetland fully depends on the supply of the river. The Niger originates in the rainforest of Guinea, where the annual rainfall amounts to 2,500 mm per year. The rainfall in the catchment area of the Niger differs, however, from year to year, thus also the annual river discharge of the Niger varies, between 2,000 and 10,000 m^3/s in the peak month. Due to this variation, the water level in the Inner Niger Delta rises some years 7 meter and in others not more than 4.5 meter. The year-to-year variation of the area being inundated by the river is even bigger, between 10,000 and 45,000 km^2.

One million people try to make their living in the Inner Niger Delta as fishermen, cattle breeders or farmers, and thus fully depend on the natural resources found within an area of 50,000 km^2. The annual production of fish and rice is determined by the river discharge and is insufficient to feed the local people in dry years.

Years with a peak discharge below 4,000 m^3/s occurred only twice between 1900 and 1980, but it has rarely been much above this level during the last 20 years. This decrease is partly due to a reduced rainfall in the catchment area of the Niger, but can also be attributed to two dams in the river, upstream of the Inner Delta. At the Markala dam, about 2.5 km^3 of water are taken each year since 1950 to irrigate 40,000 ha. 2.5 km^3 only represent 3% of the total river discharge in abundant years, but a similar amount in a poor year is equivalent to 16% of the total river discharge. The Selingué dam is used since 1982 to produce electricity for Mali capital, Bamako. Due to this dam, up to 30% of the peak river discharge might be withheld in the reservoir, but also in this case, the figure is lower when the river discharge is high.

The combined effect of both dams on the Inner Delta could be quantitatively shown. Every year, the flood in the Inner Delta is lowered by 50 cm. Consequently, as an extensive analysis of satellite images revealed, the flooded surface area is reduced by nearly 50% in years with a low river discharge. As a further consequence, the production of rice and fish (and probably also cattle) in the Inner Niger Delta is seriously limited by the two dams. Even if the two dams are profitable themselves, the effect downstream has not yet been taken into account. An overall cost-benefit analysis is urgently needed. This analysis might also be used as a tool to predict the effect of other dams being planned in the Niger River.

[1] The study is carried out by a consortium (Alterra, Altenburg & Wymenga and RIZA) led by Wetlands International. It takes place in the framework of the intergovernmental cooperation between Mali (Ministère de l'Environnement) and the Netherlands (Directorate General for Development Cooperation - DGIS, RIZA, Ministry of Agriculture, Nature Management and Fisheries), financed under the "International Nature Management Programme (PIN)". The hydrology studies are led by RIZA.