THE ECOLOGICAL CHARACTERISTICS OF THE WATER BODIES NEAR RIGA

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Like many European capitals, Riga, the capital of Latvia, is located close to several bodies of water. The Daugava River crosses the city, and several lakes are in the vicinity. This circumstance has a historical background, as it was customary to found trade and expansion centres near water bodies. Many of these cities became capitals and industrial centres due to the availability of capital, labour and water. As industrial expansion usually brought with it significant environment degradation, the surroundings of capitals were among the first polluted areas.

The first studies of the lakes in the vicinity of Riga were made by C. Grewgingk (1861), M. Gottfriedt (1877), A. Thiem (1897) and B. Doss (1903), and a more detailed study was completed by F. Ludwig (1908). In the 19 th century the influence of wastewater on natural water bodies was insignificant as the population of Riga was comparatively small and the produced waste load was quickly decomposed, i.e. self-purified, by the water bodies themselves. In the end of the 19th century the industrialisation of Riga began and the situation changed. For example, a study of algae in the Riga Channel, located in the centre of Riga, showed that the channel was slightly to moderately polluted in 1924-1927 (Graudina 1928).

The situation changed drastically after the Second World War, when Latvia was incorporated into the USSR and hyper-industrialisation began. Pollution became very significant after the 1960s as a consequence of the forced urbanisation of Riga. Since then, the main parts of Riga’s water bodies have been polluted. After the re-establishment of Latvia's independence, the economic situation in industry and agriculture became critical. This crisis sharply diminished industrial and agricultural loads and pollution, but in the meanwhile household pollution has decreased only slightly.

The lakes surrounding Riga

There are several lakes in the vicinity of Riga: Kisezers, Juglas, Mazais Baltezers and Lielais Baltezers are important recreation areas and water reservoirs. These lakes were studied already at the beginning of the 20th century (Ludwig, 1908, Zans, 1926). The data on these lakes are mentioned also in a popular edition of "Latvijas zeme, daba un tauta" (The land, nature and people of Latvia), which was published annually in the 1930s.

Table 1. Characteristics of the lakes in the vicinity of Riga.

Lake	Area (ha)	Maximum depth (m)	Mean depth (m)
Kisezers	1778	4.0	3.0
Juglas	562	3.0	1.7
Lielais Baltezers	600	5.9	2.7
Mazais Baltezers	196	10.0	4.6

The lakes are situated in the coastal lowland, Piejuras, northeast of Riga. The lakes were formed in the postglacial period as the result of two processes: sea regression and shift of streams towards the Gauja River and the Daugava River (Stakle 1935, Saule-Sleinis 1960). The watersheds are different in size (3.5-1900 km^2) and land use. Forests are the dominant feature of the land use pattern (30 to 65 %). The hydrological features are determined by the Daugava and the influx of seawater from the Gulf of Riga under strong westerly winds. A channel system, built in 1901-1903, connects the lakes. After the channel was completed, the water level in the Lielais Baltezers and Mazais Baltezers fell 1.8 metres (Kacalova et al., 1962).

Hydrochemistry of the lakes

An analysis of chemical composition of water shows the influence of the hydrological regime, namely the tide processes from the Gulf of Riga, which are more pronounced in autumn and spring in the Kisezers (Pera & Ramane, 1959; Kacalova et al., 1962). During the freshwater inflow, the mineralisation rate changes from 220 to 280 mg/l, and from 150 to 250 mg/l, in autumn and spring, respectively. In the case of seawater influx the mineralisation can reach 400 mg/l, which can cause changes in stratification as well (Rigas apkartnes ezeru…, 1995).

Table 2. Data of the lakes during the vegetation period (sample depth 0.5m) (The trophic state of lakes in the vicinity of Riga 1995)

Lake	Trans-parency m	Tempe-rature °C	pH	HCO_3^{2-} mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	SO_4^{2-} mg/l	Cl^{1-} mg/l	NH_4^{1+} mg/l	NO_2^{1-} mg/l	NO_3^{1-} mg/l
Juglas	0.6	20.6	8.0	231.3	70.5	18.7	57.6	14.2	0.1	0.04	0.8
Kisezers	0.8	19.7	8.8	186.1	60.5	22.9	60.0	153.9	0.2	0.02	0.9
Mazais Baltezers	1.2	20.1	7.5	195.2	56.3	30.5	33.0	26.98	0.43	0.05	1.3

From the 1950s to the 1990s the chemical composition of the water in these lakes was strongly affected by several pollutants in the watershed. Due to the economic situation, the load of pollutants decreased remarkably in the 1990s (Latvijas vides parskats, 1996).

Ecological characteristics

The lakes surrounding Riga have the following characteristics:

- large open water surface
- frequent mixing of water mass and aeration by winds
- domination of eurybiotic and euryhalinic species (species with wide adaptive ability to environmental conditions and water salinity)
- rapid recirculation of substances ensuring comparatively high activity of producents (phytoplankton) and reducents (bacterioplankton and bacteriobenthos).
- oxygen saturation practically never falls below 10%.

Morphometrically the lakes around Riga are eutrophic and under anthropogenic impact (Kumsare et al.,1958). Since the beginning of the 20th century an intensive runoff of nutrient substances from the drainage area has taken place, thus intensifying eutrophication: the ratio of blue-green algae in the phytoplankton community has increased. The processes of eutrophication have led to the domination of blue-green algae in phytoplankton and degradation of the trophic chain. The species diversity of zooplankton and zoobenthos organisms has decreased, along with the self-purification capacity of the lakes. At present no essential changes in the anthropogenic load are expected.

The changes in the community of algae have mainly been caused by high levels of faecal pollution (as a source of P, N and C). Since 1960 the heavy influence of faecal pollution has been observed in Lake Kisezers, and faecal pollution in Lake Juglas exceeded sanitary norms approximately 30-fold in 1982. The *E. coli* index in Lake Lielais Baltezers has ranged between 2300-23800 cells/l, and there is no source of significant bacteriological pollution. Faecal pollution is insignificant in Lake Mazais Baltezers, while at the same time the sediment *E. coli* index can reach 62500 cells/l.

Cyanobacteria blooms are often observed in water bodies undergoing increased nutrient enrichment, especially in water bodies whose nutrient status can be classified as either eutrophic or hypereutrophic (hypereutrophy is defined as the condition where nutrient inputs exceed the nutrient demands of phytoplankton). Since 1951 in the development of phytoplankton an increase in the blue-green algae ratio has been observed. In 1991 the blue-green algal biomass comprised 97% of all algae biomass in several of the lakes.

The limiting factor of eutrophication in the lakes near Riga is phosphorus. Mass occurrences of algae can be expected in waters where the ratio of main nutrient elements (mineral phosphorus, nitrogen and carbon) is close to the proportion of these elements in the algae biomass, C: N: P=106:16:1. In 1959 in Lake Kisezers the P/N ratio was 1/333, but in 1991 it was 1/130. In Lakes Jugla, Lielais Baltezers and Mazais Baltezers the situation was similar. The development of blue-green algal blooms is stimulated also by the hydrological regime in Lakes Kisezers and Lielais and Mazais Baltezers. An important feature is mixing of fresh water with inflowing seawater.

Since 1959 an increase of *Rotatoria* has been observed in the zooplankton community. *Rotatoria* feed on phytoplankton about 10-15 μm in diameter, thus increasing the mineralisation of organic substances. They are also adaptive to the wide fluctuations in environmental conditions. The ratio of crustaceans in the zooplankton has decreased, which may be a reason for decreases in fish catches and self-purification.

The concentrations of heavy metals in the lakes are considerably higher than maximal remission concentrations (MPC) in comparison with European standards. For example, Hg>1.0 mg/l decreases the growth of algae (the European standard is Hg<1.0 mg/l), and at a Cu concentration of 10 mg/l algal growth diminished by 50%. In Lake Mazais Baltezres the concentration of Cu is 3.5 mg/l, and at some sites in Lake Juglas it is 16.5 mg/l.

River Daugava

The Daugava is the most important river in Latvia, not only due to its historical importance, but also as a source of energy and as a reservoir for drinking water for Riga. It is the largest river of Latvia with a total length of 1005 km. Its drainage area is 87 900 km^2 in the territories of five countries (Russia, Belarus, Lithuania, Estonia and Latvia), and 24 700 km^2 or 39% of the total watershed belongs to Latvia (Latvijas Daba, 1994).

Geologically the Daugava River basin is covered by glacial deposits to depths of 200 metres. The greatest part of these deposits consists of Weichselian (Latvian) Glacial, characterised by till, sandy till and glaciolacustrine sand. After
the Ice Age alluvial matter were deposited (Kurss, Stinkule, 1997).

At its source in Lake Dvineca, the Daugava is only six to eight metres wide, and further downstream the depth of the river valley can be as much as 50 m. Above and below the city of Vitebsk the river flows through dolomite rocks and there are many rapids with depths varying from 0.8 to 3 metres. On the Latvian border the Daugava runs through an old, narrow valley where the river is 200 m wide. The discharge of these stretches is approximately 2/3 of the discharge in the middle part. The stretch from Kraslava to Daugavpils is very curved with many rapids. The fall varies from 0.10 to 0.15 m/km and the velocity varies between 0.3 m/sec and 0.7 m/sec in the rapids. Below the city of Daugavpils in the eastern Latvian lowlands, the river runs slowly in gently sloping banks and wide floodlands. The riverbed is rather sandy with sandbanks typically causing ice jams in winter. Near Krustpils the Daugava flows more rapidly.

The Daugava has three hydroelectric power stations. The Plavinu Reservoir is the first one, with an area of 34.9 km^2 (Table 3). The dam, constructed in 1962, caused the water level to rise to 35 m, thus creating the largest reservoir in Latvia. The Keguma hydroelectric power plant (HPP), constructed in 1939, lies 50 km from the mouth of the Daugava, and is smaller than the others. The third and last power station on the Daugava is the Riga hydroelectric power station. The total length of this installation, completed in 1974, is 27 km. The hydrochemical parameters of the reservoirs are presented in Table 3. In its last stretch of 30 km (below the Rigas Reservoir) the river is from 370 to 750 m wide and from 5 m to 15 m deep. A typical feature of this stretch is brackish water inflow (up to 22 km from the mouth), which has been enhanced by the lack of slope.

Table 3. Data on the water reservoirs (according to Klavins et al., 1992, 1995)

Reservoir	Area km^2	Mean depth m	Maximum depth m	Volume million m^3	Retention time times a year
Plavinu	34.9	14.6	42	509	33
Keguma	24.9	9.5	16.5	157	27
Rigas	42.4	7.5	18	339	19

Hydrochemistry of the Daugava River

The sediment of the Daugava River has been notably transformed by the operation of the hydroelectric power stations. This transformation is particularly evident in the process of self-purification. The investigations of the Laboratory of Hydrobiology, Institute of Biology of Latvia (unpublished reports), indicate that the following changes have taken place. Oxygen saturation has increased by 10-15 %, the amount of organic matter has decreased by 20% (easily oxidised organic matter by 7-10%), inorganic nitrogen has decreased to 25-27 % of the previous values, and no changes in concentrations of mineral phosphorus have been observed. Moreover, the self-purification capability of the Daugava is particularly effective due to geomorphological factors (e.g. river fall, high degree of meanders, dolomite or sandy bedrock). At the same time the water quality of the regulated part of the Daugava has been shown to decline during vegetation seasons: reduction of oxygen levels 15 %, of organic matter by 18-20% (easily oxidised organic matter by 50%), of mineral nitrogen content by 67%, and of phosphorus content by 30%. This shows that accumulation is a dominating process.

Increased amounts of several pollutants have been observed in sediments. Sediment analyses have shown increased concentrations of several heavy metals: Pb, Cd, Cu and Ni (Klavins et al., 1992). High amounts of Fe, Mn, Zn and Cu have been noted in the lower Daugava, partially due to the geochemical characteristics of the river (Table 5). At the same time high concentrations of Cd and Pb (18-35 mg/kg) indicate a strong anthropogenic impact (Klavins et. al., 1995).

Table 4. Hydrochemical characteristics of the Daugava River during the vegetation season (measured at a depth of 0.5 m, unpublished data)

	Temp C^o	O_2 mg/l	BOD_5 mgO_2/l	Color Pt/Co	$N\text{-}NO_3$ mg/l	HCO_3^{2-} mg/l	$P\text{-}PO_4$ mg/l	Fe mg/l	Si mg/l
Dvina	12.7-15.9	6.6-7.3	1.5-1.7	30-100	1.08-0.79	120.1	0.017-0.078	0.19-0.40	1.2-2.6
Daugava upper part	15.4-16.2	5.14-8.7	1.7-2.0	31-72	0.3-0.4	138.7	0.018-0.050	0.25-0.42	1.4-4.2
Rigas Reservoir	19.9-17.0	6.2-9.2	1.2-2.2	39-100	0.3-1.1	155.6	0.011-0.060	0.2-0.45	1.8-2.7
Plavinas Reservoir	20.0-16.5	6.0-8.9	1.2-2.8	31-82	0.2-0.8	170.8	0.054-0.095	0.31-0.49	1.7-2.9
Keguma Reservoir	18.6-16.5	6.3-8.5	1.2-2.8	39-87	0.3-0.7	158.6	0.021-0.080	0.40-0.50	1.7-2.8
Daugava lower part	16.0 - 20.7	6.3-0.2	2.1-4.5	25-99	1.5-2.2	170.5	0.01-0.2	0.30-0.50	2.0-2.9

Table 5. Heavy metal concentrations in the sediment of the Daugava (according to Klavins et al., 1992)

River stretches	Lead (Pb) mg/kg	Copper (Cu) mg/kg	Cadmium (Cd) mg/kg	Nickel (Ni) mg/kg	Cobalt (Co) mg/kg
Middle Daugava	9.75	4.50	1.05	4.72	3.75
Lower Daugava	65.50	16.25	2.20	24.38	5.06

The bacteriological state of the Daugava has been studied by A. Melberga and G. Springe (Melberga et al., 1966, 1974; Springe et al., 1995; unpublished reports of the Laboratory of Hydrobiology, Institute of Biology of Latvia, 1978, 1980, 1987, 1991).

Ecological characteristics

According to these studies the following conclusions can be drawn:

- The river stretch from the border between Latvia and Belorussia is slightly polluted to considerably polluted.
- In general a low number of saprophytic bacteria and oil-decomposing bacteria have been measured in the water, as well as in the sediments of the reservoirs.
- An increase in total bacteria was noted in Plavinu Reservoir from 1981 to 1991, which reflects the tendency toward eutrophication. A similar phenomenon has also been observed in Rigas Reservoir.
- According to microbiological characteristics (bacterioplankton and bacteriobenthos) the lower reaches of the Daugava are slightly to considerably polluted.

The self-purification capacity of the Daugava is higher in the river itself than in the reservoirs, where eutrophication can be detected. According to the data on phytoplankton communities, the Daugava is considerably polluted, especially below the cities (Druvietis 1978; 1980; 1981). In the lower reaches of the Daugava the impact of unstable environmental conditions characterizes the ecological state of the river, e.g overgrowth by macrophytes has been noted (Latvijas Daba, 1994).

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