Lund University
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Assessment of Efforts to Solve the Water Pollution Problem in Kaunas

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Summary

The pollution in the Nemunas river which is the fourth longest river in the basin of the Baltic Sea, increases significantly downstream Kaunas city. The city with more than 400 000 inhabitants and 120 big industries discharges untreated wastewater into the river. The assessment of Kaunas effect on the Nemunas river is complicated by the tributary Neris which brings a high amount of pollutants to the Nemunas within Kaunas city area. According to some studies, Kaunas wastewater load accounts for 1/3 of the increase in organic material and nutrients downstream the city, the Neris river accounts for the other 2/3 of the increase.

The analysis of national environmental strategy and corresponding legislation shows that the pollution of surface water is one of the biggest environmental concerns in Lithuania. New wastewater norms, surface water standards and enforcement by economic instruments are directed to abate urban pollution load. Priority financial investments with the help of international funds are granted towards Kaunas Water and Environment Project to improve the water and wastewater management. The main part of that project is Kaunas Wastewater Treatment Plant. The first phase of the plant, mechanical treatment with chemical phosphorus precipitation will be put into operation in summer 1999.

Kaunas wastewater load on the river has decreased by half since 1991. The data suggests that the domestic wastewater reduction is achieved by water saving. The industrial wastewater reduction is caused by a general recession in production, the recently introduced economic incentives to reduce wastewater pollution, and Cleaner Production programmes. The amount of domestic wastewater is predicted to stabilise in the near future due to reduced incentives to save more water. The total volume of industrial wastewater started to increase in 1997 and it is predicted to increase slowly for some years as industrial production recovers from the economic crisis. Predictions for the future are difficult to make due to inaccurate data on the number of domestic water meters and measurements of wastewater production in industries.

The wastewater effect on the river water quality will depend on the amount of wastewater produced and the technical efficiency of the treatment plant in the future. The main contaminants, except for nitrogen and nickel, will be removed by 60 - 90% in the first phase of the plant. The results of the Stella model shows that the wastewater treatment will affect the load on the river less than economic recession and incentives affected it 1991 - 1997.

The main concern of the water management and monitoring in Kaunas is the physical and chemical quality of the river water, but very low attention is paid to the impact of urban wastewater on the river ecosystem and the social welfare of the local population. One of the main objects in water management, Kaunas Wastewater Treatment Plant lacks Environmental Impact Assessment. The analysis of environmental impact shows that eutrophication increases and fish diversity diminishes downstream Kaunas. Water management may reduce this impact by 20% in the future. The analysis of social impact outlines the quality of potable water and possibilities for recreational bathing. The data suggests that the discharge of wastewater does not affect groundwater for Kaunas city. The risk for possible negative effect will be reduced in the future due to the transfer of wastewater outlet downstream the city and due to the wastewater treatment. Because of the bacteriological water pollution, beaches along the Nemunas in the city are closed. After the transfer of the sewerage outlet, water quality will improve and the beaches will be suitable for bathing. The Stella model shows that bacteriological pollution will not exceed the limits in the Nemunas downstream Kaunas only after the biological wastewater treatment plant.

One of the main conclusions of the assessment of Kaunas efforts to reduce pollution in the Nemunas river is that there is a lack of integration of environmental and social objectives in the water management practices.

Introduction

The importance of the water pollution problem caused by the city is proved by the fact that Lithuanian Environmental Ministry and Helsinki Commission (HELCOM) have given the highest priority for construction of a municipal wastewater treatment plant in Kaunas city. The first phase of the wastewater treatment plant is being constructed by now and it will be put into operation in summer 1999. Even if the wastewater management in Kaunas has received big local and international investments, all the attention has been paid to the technical and financial capacity of the treatment plant and improvements in the sewerage system. This paper analyses the effect of the water management on the natural and social environment.

Technical capacity of the plant and possible improvements in the Nemunas river quality which is a recipient of untreated Kaunas wastewater were analysed by different projects and studies. However, results of other management measures which have been implemented since 1990 to provide incentives to reduce wastewater production and pollution were not evaluated and they received less attention in prediction of the future urban load on the river. This paper overviews the water management measures used to solve the river pollution problem and analyses factors for wastewater reduction in Kaunas.

While large financial resources are being dedicated to reduce contamination of the wastewater, very low attention is paid to analyse the impact of wastewater caused on the ecosystem of the Nemunas and on the social welfare of local population. Environmental legislation and water management practice in Kaunas limit themselves on the fact that highly contaminated wastewater pollutes the river not analysing what implications this pollution causes to the natural and social environment and which improvements the adopted measures will bring to the natural and social well-being. This paper analyses the environmental impact on the river ecosystem and the social impact on Kaunas population caused by wastewater now and in the future.

Objectives

1. To describe the problem of surface water pollution in Kaunas and the main pollution sources.
2. To identify water management system and its objectives.
3. To analyse factors for the wastewater reduction and effect of the wastewater on water quality in the Nemunas river.
4. To analyse impact of the wastewater on the river ecosystem, especially eutrophication and changes in diversity of fishes.
5. To analyse social impact of the wastewater management, especially impact on potable water quality and on recreational bathing in the Nemunas river.

Methodology

System analysis is used to get understanding about the water management system, about its boundaries, external factors and effects on surrounding environment. The concept that management should consider not only primary effects, but also secondary effects (impact) is kept through all the work.

Water quality data are analysed comparing parameters to the corresponding Lithuanian Highest Allowable Concentration (HAC) described in the standards.

Some mathematical models are created using Stella software. The models simulate scenarios for particular problems in order to identify effects of water management in the future.

Object of the analysis

The scope of the paper covers water management including legislative, regulative, economic and technical measures and its effects on environment.

The object of the analysis is displayed in figure 1. The paper starts with a description of the water pollution problem in Kaunas city which is in the centre of the object of the analysis. The main causes of the pollution - contamination of wastewater, amount of wastewater and pollution in the Neris river are also described in the first chapter. The second chapter deals with the water management system from environmental objectives of legislation down to the wastewater treatment plant and economic incentives for water saving and wastewater reduction. The third chapter analyses the results of the management in reduction of the wastewater pollution more detailed and predicts pollution in the Nemunas river in the future due to the effect of wastewater. The last chapter concentrates on the bottom part of the object of the analysis shown in figure 1. General objectives that are given in Italics in the figure are written in the Lithuanian Environmental Strategy. The impact on river ecosystem and on social well-being are analysed in details.

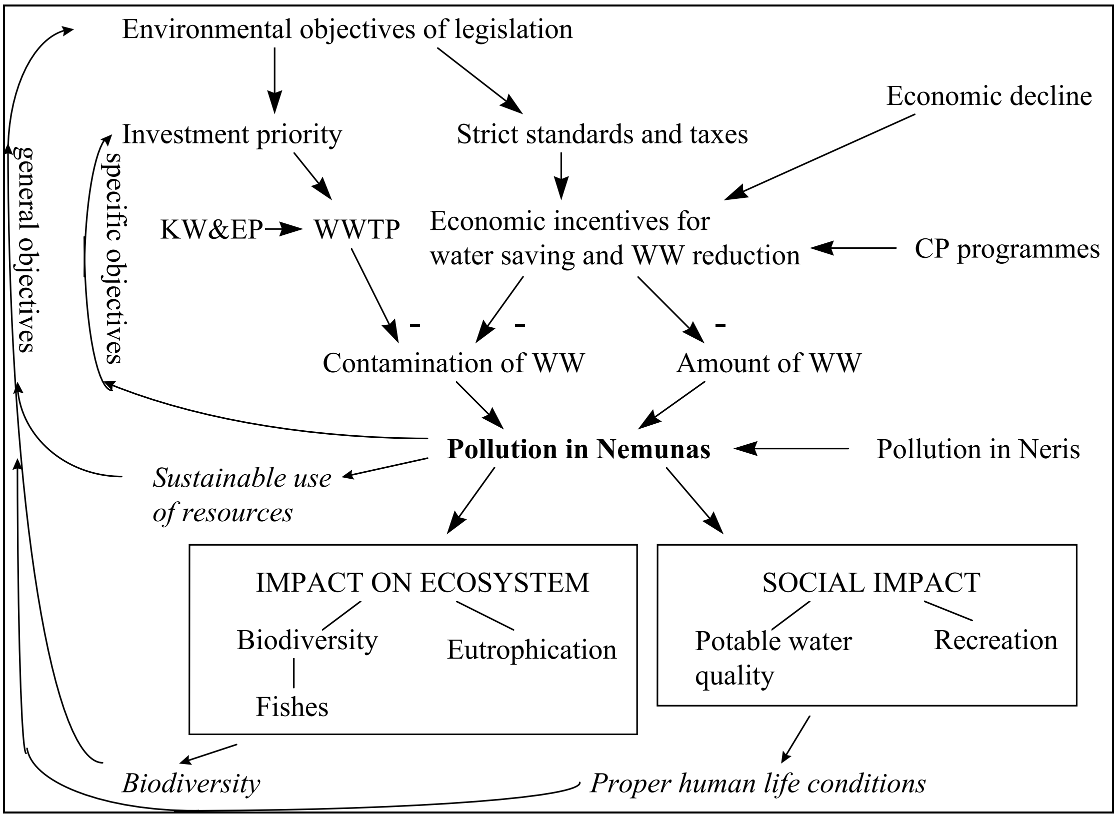


Figure 1. Object of the analysis.

I. SCALE OF WATER POLLUTION IN THE NEMUNAS DOWNSTREAM KAUNAS CITY

Geographical background

The Nemunas river is the fourth longest river in the basin of the Baltic Sea and the biggest river in Lithuania. Its length amounts to 937km. The Nemunas drainage basin area is 97 924km^2. The Nemunas river from the source to 475km flows through the territory of Byelorussia, from 457.7km to 111.9km and from 13.2km to the mouth - through the territory of Lithuania. In other distances the Nemunas marks off the border between Lithuania and Byelorussia and between Lithuania and Kaliningrad region (Russia). The Nemunas flows into the Curonian Lagoon (Kuršių marios), a half-closed lagoon of the Baltic Sea. 47.5% of the Nemunas basin area belong to Lithuania. (*Kilkus K., 1998; Jablonskis J. et al., 1993*)

In the Kaunas city zone there are many specific points such as big Kaunas water reservoir, a dam, Lampedziai reservoir and inflow of the two biggest Nemunas tributaries. Kaunas city is located around the Nemunas river, 225 - 200km before its mouth. The city marks off the conventional boundary between the Middle Nemunas and the Lower Nemunas. The mean flow of the Nemunas river upstream Kaunas city is 235m^3/s, downstream Kaunas - 375m^3/s. The Nemunas river upstream Kaunas was dammed up in 1959 to prevent Kaunas from flooding and use hydropower for electricity production. The capacity of the Hydropower Plant is 100.8MW. Annual electricity production is 380GWh. When it was constructed, it was a major producer of electricity for the region, but now it covers less than 15% of the city needs. Kaunas reservoir (Kauno marios) occupies 63.5km^2 territory and contains 460 million m^3 water. (*Maniukas J., 1977*)

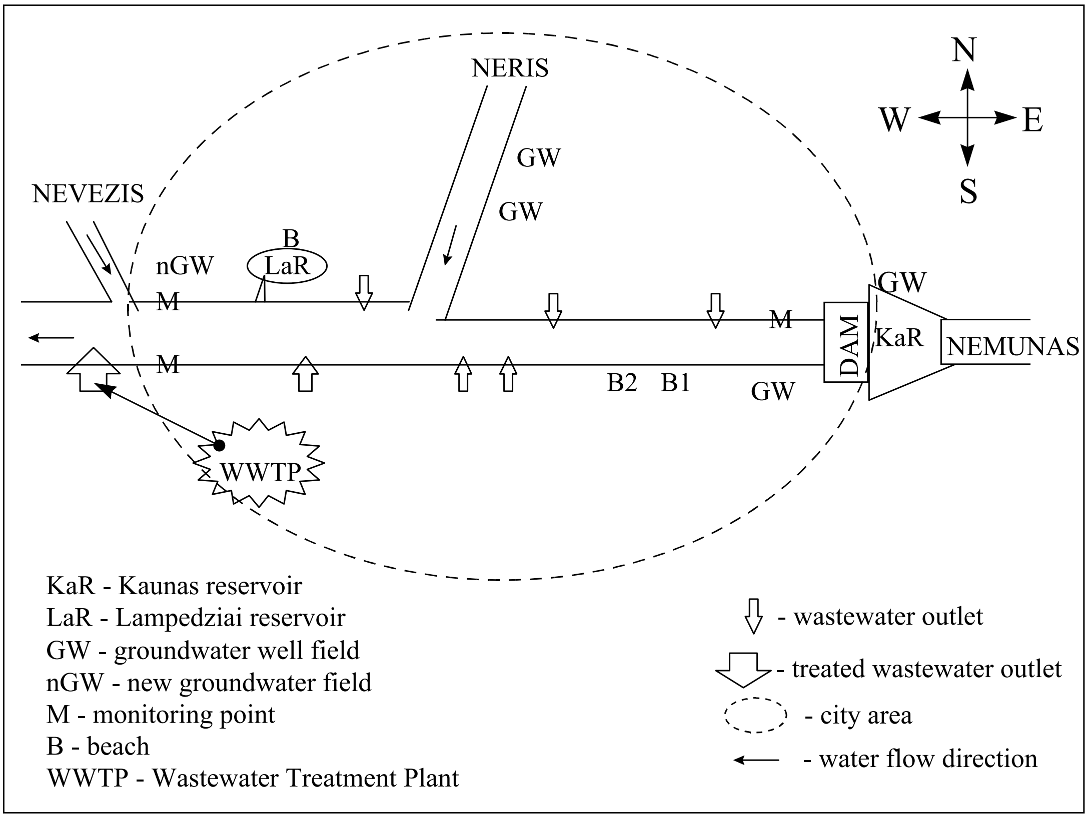


Figure 1.1. Plan of the water system in Kaunas city.

Lampedziai reservoir (Lampėdžiai) is an old gravel-pit territory filled with water naturally after its utilisation. The water in the reservoir adjoins the Nemunas river, but water quality in the reservoir is much better than in the river.

Within Kaunas city the Neris river flows into the Nemunas. The Neris is the biggest tributary of the Nemunas. The basin area of the Neris is 24 492km^2. The source of the Neris river is in the territory of Byelorussia. More than 140km upstream Kaunas, the Neris river flows through Vilnius, the capital of Lithuania, that has population of more than 500 000. Farther downstream, 36km before Kaunas, the Neris flows through the town of Jonava with about 30 000 inhabitants. The mean flow of the Neris before the confluence with the Nemunas is 152m^3/s.

Downstream Kaunas the Nevezis river (Nevėžis) converges with the Nemunas. The Nevezis is a river flowing through areas of highly intensive agriculture. The basin area of the Nevezis is 6141km^2. Its water flow before the confluence with the Nemunas is 33m^3/s and its effect on the water quality in the Nemunas is much lower than the effect of the Neris.

Below the Nevezis only small tributaries supplement the reach of the Nemunas. Next bigger town located 80km from Kaunas downstream the Nemunas is Jurbarkas with about 15 400 inhabitants. (*ESE, 1986; Jablonskis J. et al., 1993*)

Kaunas city is the second largest city in the Nemunas drainage basin and the biggest city located around the river reach. It has a total population of 413 045. The territory of the city has grown and it encompasses both riversides of the Nemunas and the Neris. Kaunas is an industrial city with textile industry having the biggest production share. Main production sectors of industry are the following:

- light industry (mostly textile)	36.4%
- building material	22.6%
- food processing	17.1%
- chemical industry	5.8%
- wood and paper	5.3%

Kaunas has about 500 registered industries. There are 120 big industries which consume more than 50 m^3 water per day. (*SV, 1997a; KS, 1997*)

Water quality in the river

Pollution load brought by the Nemunas river is one of the largest in the Baltic Sea region. Curonian Lagoon which is a recipient of the Nemunas stream is unable to decompose high loads of organic material and is highly eutrophicated. Concentrations of nutrients in the mouth of the Nemunas are about two - three times higher than naturally occurring concentrations. (*HELCOM, 1993a*)

Water quality in the river is influenced by non-point pollution from cultivated land areas and by urban point sources. Urban pollution load comes from households and industries with insufficient or without no wastewater treatment. In the Lower Nemunas about half of the pollution arises from agriculture and half from the cities. For many years the biggest polluters have been Sovetsk, Neman (Kaliningrad region, Russia), Kaunas, Alytus and Jurbarkas (Lithuania) (*BEF, 1998; Vinceviciene V., 1996*).

Concentration of oxygen consuming substances (measured as BOD_7) and suspended matter is very low upstream Kaunas due to the dam. The dam on the Nemunas river and the reservoir located upstream Kaunas act as a natural sedimentation and purification tank reducing amount of BOD_7 and suspended matter significantly. For example, average BOD_7 upstream the reservoir is more than 5mgO_2/l while average BOD_7 downstream the dam is less than 3mgO_2/l. Due to the inflow of Kaunas wastewater and of the Neris, water quality in the

Nemunas deteriorates while it flows through the city. For example, average BOD_7 downstream the city is about 4 - 6mgO_2/l. (*LEPM, 1997*)

The effect of Kaunas on the Nemunas can be partly explained by comparison of water quality upstream and downstream the city. Most of the Nemunas water quality characteristics exceed highest allowable concentration (HAC) downstream Kaunas and some characteristics exceed HAC even upstream Kaunas. In 1994 - 1997 BOD_7 altered between 1mgO_2/l and 7mgO_2/l upstream Kaunas and between 1mg/l and 12mg/l downstream Kaunas (HAC for BOD_7 in Lithuania is 2.3mgO_2/l). Concentration of suspended material altered between 1mg/l and 10mg/l upstream Kaunas, while during spring flood it reached 18mg/l. Suspended material downstream Kaunas was 1 - 17mg/l and during spring flood 28mg/l. Concentration of dissolved oxygen altered between 15 and 5mg/l upstream Kaunas and between 15 and 3mg/l downstream Kaunas (HAC for dissolved oxygen is $\geq$ 6mg/l). Total nitrogen concentration was 0.4 - 3.4mg/l upstream Kaunas and 0.93 - 4mg/l downstream Kaunas (HAC for total N is 2mg/l). Total phosphorus upstream Kaunas exceeded HAC seldom, but total phosphorus downstream Kaunas was 0.13 - 0.34mg/l (HAC for total P is 0.2mg/l). Concentration of phosphates upstream Kaunas was 0.01 - 0.22mg/l, it was much higher downstream Kaunas and it reached 2mg/l (HAC for phosphates is 0.08mg/l). Minimum, average and maximum values of dissolved oxygen, BOD, nitrogen and phosphorus in 1997 are displayed in figure 1.2.

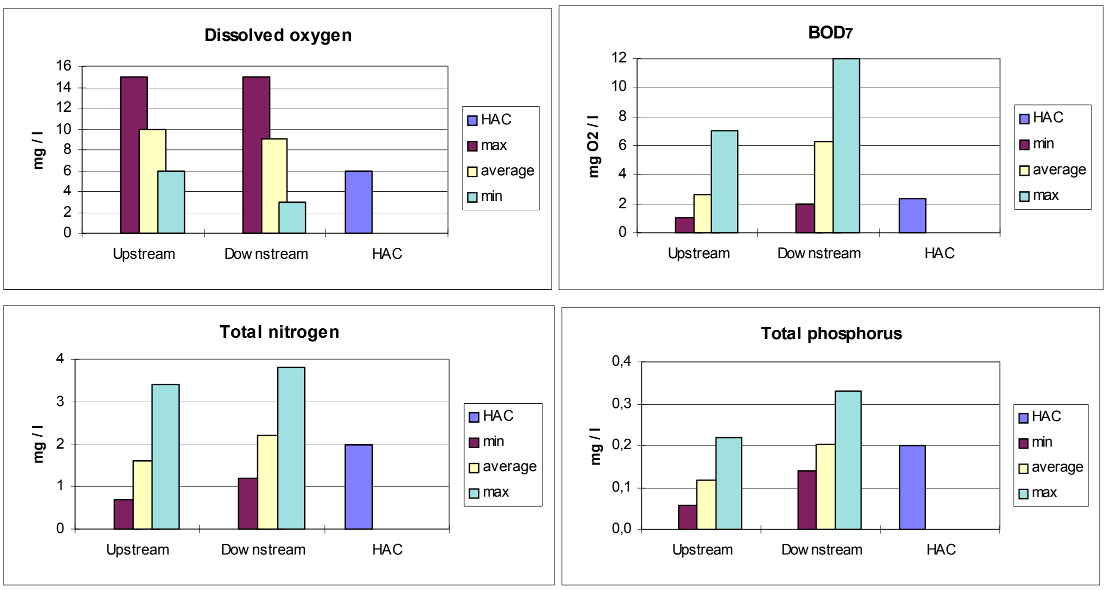


Figure 1.2. Concentration of dissolved oxygen, BOD_7, total nitrogen and phosphorus in the Nemunas upstream and downstream Kaunas and Highest Allowable Concentrations (HAC). (Data source - Joint Research Centre)

Concentration of some heavy metals was higher than allowable concentration in 1994 - 1997. Concentration of copper exceeded HAC till 2.9 times upstream the city and till 5 times downstream the city. Concentration of zinc exceeded HAC a few times and maximum concentration reached 1.6 HAC upstream Kaunas and 2.2 HAC downstream Kaunas (HAC is 10µg/l). Concentration of chromium and nickel did not exceed HAC (HAC is 5µg/l and 10µg/l respectively). Concentration of detergents exceeded HAC till 1.3 times upstream Kaunas and till 1.9 times downstream Kaunas. Average concentration of oil products exceeded HAC till 1.14 times upstream Kaunas and till 2.8 times downstream Kaunas (HAC for oil products is 0.05mg/l). (*LEPM, 1997; Dudutyte Z., 1998*)

Bacteriological pollution in the Nemunas increases downstream of the city. In Kaunas reservoir bacteriological pollution, measured as Coli index, does not exceed HAC for bathing ($5*10^3$ coliform bacteria per litre). HAC is already exceeded in the area of the two beaches within Kaunas city (refer to the map in figure 1.1). Downstream Kaunas bacteriological pollution is enormous and Coli index reaches values of 10^5 - 10^7 bacteria per litre. The changes of Coli index in the Nemunas in Kaunas city zone in summer 1997 are shown in figure 1.3. Cleanest water belongs to the class I and has Coli index < 10^3, class II has Coli index < 10^4, etc., class VI has Coli index > 10^7.

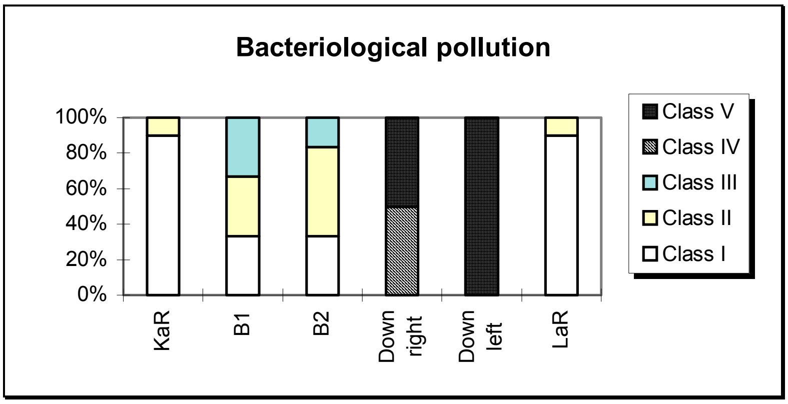


Figure 1.3. Bacteriological pollution in the Nemunas river and Lampedziai reservoir. (Data sources - Kaunas Public Health Centre and Joint Research Centre)

Note: KaR - Kaunas reservoir; B1 and B2 - beaches in the Nemunas river; Down right - downstream the city at the right bank; Down left - downstream the city at the left bank; LaR - Lampedziai reservoir.

The water quality in the river fluctuates due to the changes in hydro-meteorological conditions and the natural cycle of vegetation. Hydrology of the Nemunas in Kaunas city zone is determined by the dam and working regime of Kaunas Hydropower Plant. Kaunas dam is used to prevent flooding in Kaunas area and to regulate, to smoothen fluctuation of the water level during heavy rains and droughts in the Lower Nemunas. In winter the Nemunas downstream Kaunas is frozen only very short time (16 days on average). During the cold period (October - March) self-purification process is less intensive. Then vegetation is inactive, biological processes are slower, degradation of organic material is low. Nitrogen and phosphates are not used up by organisms and their concentration increases. In spring due to the increase in temperature and the abundance of nutrients, algae start growing intensively and eutrophication of the river becomes evident. Then vegetation is dominated by a few algae species, turbidity of water is high and light penetration to lower layers is weak. When algae use up the nutrients by producing a high amount of organic matter and oxygen, the degradation of organic matter intensifies which uses a high amount of oxygen leading to a deficiency of oxygen for the living organisms, especially, in the lower layers of the water body. (*LEPM, 1997*)

Pollution sources

Two main sources polluting the Nemunas river in Kaunas city zone are urban wastewater from Kaunas city and the Neris river.

Urban wastewater

Wastewater production

According to the origin, wastewater is domestic, industrial, commercial and urban stormwater. Domestic wastewater is water coming from households, i.e. from kitchen, bath, toilet, etc. Domestic wastewater is contaminated with organic material, nitrogen, and phosphorus mainly. Industrial wastewater includes industrial process water and water from service facilities for staff in the industrial plant usually. Contamination of industrial wastewater varies very much depending on type of the industry and pre-treatment facilities for wastewater in the industrial plant. Discharges from food industry consist of oxygen consuming substances (BOD or COD), nitrogen, phosphorus and suspended solids. Surface coating and plating industries, tanneries discharge dissolved metals, such as copper, chromium, zinc, as well as oxygen consuming substances, detergents.

Commercial wastewater is water coming from service sector, i.e. schools, restaurants, hospitals and other non-industrial institutions. The quality of commercial wastewater is similar to domestic wastewater. Urban stormwater consists of precipitation on the urban territory that has percolated through the ground or streamed down directly to the drainage system. Rain washes away contaminants from the surface and thus urban stormwater contains more pollutants than rain water. 80 - 90% of the sewerage network in Kaunas is built as a separate system where urban stormwater and sewage flow through separated pipes. The other part is combined system where stormwater is mixed with domestic and industrial wastewater. (*SV, 1997a*)

Kaunas wastewater system discharged 24 million m^3 wastewater in 1997. It is calculated that 55% of the wastewater are coming from domestic sector. About 70% of Kaunas population are served by municipal sewage system. It accounts for 290 000 inhabitants. Commercial sector produces about 15% of wastewater. Industrial wastewater comprises to 30% of total sewage volume. Virtually all significant industrial and commercial premises are connected to the sewerage. The only industrial complex that is not connected to municipal wastewater system and is not served by Kaunas Water Company is in the Eastern suburban part of Kaunas; the complex produces 7.7% of total wastewater flow. In Kaunas city there are 120 industries producing more than 50 m^3 wastewater per day. The largest factories discharging between 0.5 and 1 million m^3 wastewater per year are the two food processing factories, one brewery and textile company. (*K-Konsult, 1994; SV, 1997a; SV, 1997b; Dudutyte Z., 1998*)

Kaunas sewerage system discharges wastewater through several outlets into the Nemunas river. In the beginning of 1998, 6 outlets discharged municipal wastewater. The outlets are shown in figure 1.1. Marveles (Marvelės) outlet that is located at the left bank of the river close to the new wastewater treatment plant discharged about 2/3 of total wastewater flow.

Wastewater contamination

Wastewater from the city of Kaunas is discharged directly into the river almost with no treatment. The only existing treatment facilities of municipal wastewater are two screen chambers that are manually scrapped. Approximately 50% of the wastewater pass through these chambers. The chambers are in a poor condition. Some of the industries have pre-treatment facilities before discharge of wastewater into the municipal sewage network. Kaunas Wastewater Treatment Plant with mechanical treatment and chemical precipitation is under construction now. 95% of Kaunas wastewater will be directed to the treatment plant in summer 1999 when opening of the plant is planned. (*K-Konsult, 1994*)

The wastewater brings a high amount of pollutants to the Nemunas river. Wastewater from Kaunas discharged 6106 tons of organic matter (calculated from biochemical oxygen demand), 157 tons of phosphorus, 1184 tons of nitrogen and 67.6 tons of oil products in 1997. Because of lack of pre-treatment in industries, comparatively high amount of heavy metals was registered. In 1997 Kaunas wastewater contained 2.4 tons of chromium, 2.5 tons of copper, 0.4 tons of nickel and 12.8 tons of zinc. Comparison of average concentration of the main elements in the wastewater and their norms is shown in table 1.1. For BOD, suspended solids and nutrients allowable annual mean concentration is given in the effluent norms. All the substances exceeded the norms. For oil products and heavy metals maximum momentum concentration is determined in the norms. Even average concentration of oil products and zinc in 1997 exceeded the maximum momentum concentration. Copper exceeded maximum momentum concentration 8 times out of 72 measurements in municipal sewerage. Chromium and nickel did not exceed the norms.

Table 1.1. Mean concentration of pollutants in Kaunas wastewater and the effluent norms. Concentration in mg/l.

	BOD_7	Suspended solids	Total P	Total N	Oil products	Cr	Cu	Ni	Zn
Waste water [1]	180	158	4.59	34.9	2.0	0.072	0.073	0.012	0.379
Norm [2]	15 [3]	25 [3]	1.5 [3]	15 [3]	1 [4]	0.5 [4]	0.1 [4]	0.2 [4]	0.3 [4]

Note: [1] - Data from Kaunas Water Company;
[2] - Lithuanian basic pollution norms for wastewater discharged into surface water bodies, *LAND 10-96*;
[3] - allowable annual mean concentration (for more than 100 000 population);
[4] - maximum momentum concentration.

The Neris river pollution load

It was mentioned before that the Neris river brings high pollution load to the Nemunas river. Water quality in the Neris depends on non-point agricultural pollution and discharge of urban and industrial wastewater from Vilnius and Jonava. Highest pollution in the Neris river is downstream Vilnius. The water purifies partly while it flows further, but due to the addition of pollutants from other sources the Neris river quality before the confluence with the Nemunas is unacceptable, i.e. below the standards.

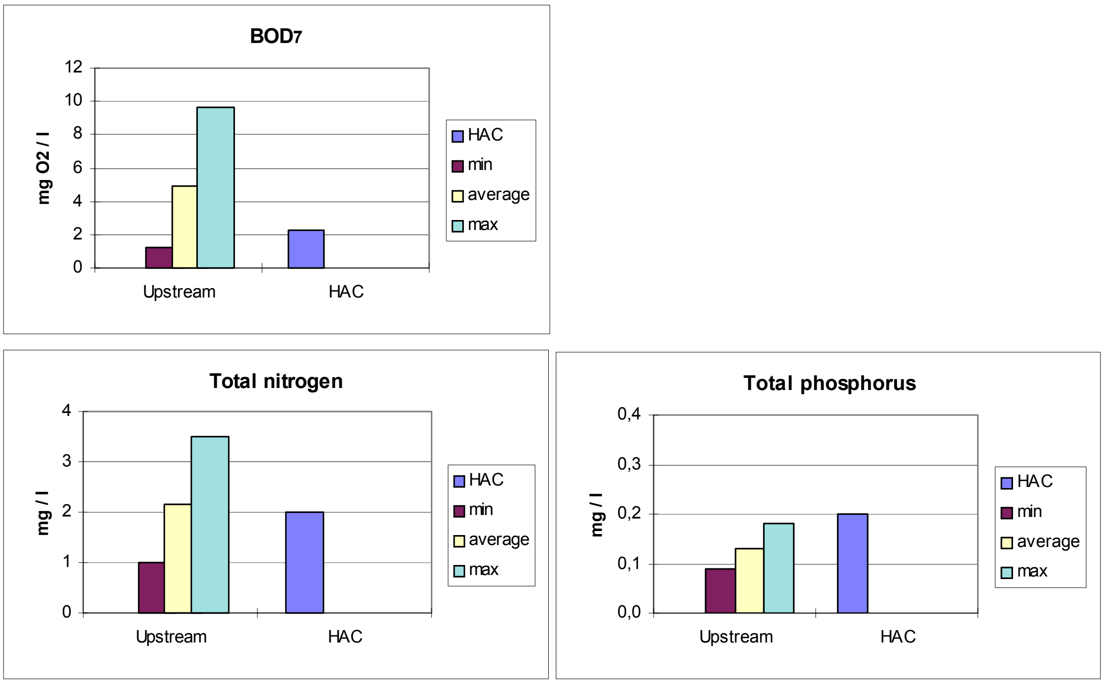


Figure 1.4. Concentration of BOD_7, total nitrogen and total phosphorus in the Neris river upstream Kaunas and Highest Allowable Concentration (HAC). (Data source - Joint Research Centre)

In 1997 concentration of organic material exceeded permissible concentration almost all the year in the Neris upstream Kaunas. BOD_7 value increased during summer significantly and it reached 8.9mgO_2/l in August and 9.6mgO_2/l in September (HAC for rivers is 2.3mgO_2/l). In the cold period mean BOD_7 reduced to 1.2 - 4mgO_2/l. Concentration of nitrogen and phosphates was low during summer and it was much higher during winter and spring. Concentration of mineral nitrogen was 0.2mg/l in August and 2.7mg/l in March 1997. Concentration of phosphates was less than 0.02mg/l in August, but it reached 0.11mg/l in

February (HAC for phosphates is 0.08mg/l). Concentration of total phosphorus did not exceed HAC. Minimum, maximum and average concentrations of BOD_7, total nitrogen and phosphorus in 1997 are shown in figure 1.4.

Concentration of detergents in the Neris did not exceed HAC. The river was not polluted with coliform bacteria and Coli index did not exceed HAC.

Other pollution sources

Other pollution sources such as direct precipitation and agricultural runoff have small effect in Kaunas city zone compared to urban wastewater and the Neris river load.

Surface of the Nemunas river in Kaunas city zone is insignificant compare to the area of the city, direct precipitation on the river surface is not considered an important pollution source. Atmospheric pollution influencing surface water quality through precipitation over urban territory is included in contamination of urban stormwater.

Non-point agricultural pollution affects water quality when the river flows through agricultural areas and this happens only about 20km downstream Kaunas. Impact of agricultural runoff is not analysed as the main interest of the study is pollution originating in Kaunas and the impact of water management in the city on the Nemunas river ecosystem. Agricultural impact on water quality upstream Kaunas is included in characteristics of water quality measured in the Neris and in the Nemunas before flowing through the city.

In conclusion, pollution in the Nemunas downstream Kaunas is an urgent problem. The Neris river brings high amount of pollutants to the Nemunas. Still pollution load from the city coming with untreated wastewater is large and water management in the city could improve water quality downstream Kaunas.

II. WATER MANAGEMENT SYSTEM

National environmental strategy (emphasis on the water pollution problem)

Environment is not among the highest national priorities in Lithuania. After the restoration of independence in 1990, the new Lithuanian Government included environment into its priorities. Later because of unfavourable economic situation, attention to environment on the highest level decreased. However, environment remains one of the national interests and a lot has been done in environmental legislation, enforcement and management since 1990. (*RECCEE, 1995*)

The latest Lithuanian Environmental Strategy was approved by the Government in 1996. When planning the action programmes to achieve the goals, the main environmental principles are taken into consideration. The principles of sustainable and consistent development, best environmental practice, best available technology are supplemented by precautionary principle, prevention principle, polluter/user pays principle, subsidiarity principle, environmental policy integration, partnership and sharing of responsibilities, and information availability. These principles prepare feasible background for environmental policy and legislation, but they have to be efficiently implemented in each programme in order to achieve proposed results. (*SRL, 1997b*)

Lithuanian Environmental Strategy expresses a big concern about surface water quality. The strategy states that ‘priority problems to be addressed are: water and air quality, waste management, preservation of natural resources, landscape and biological diversity’. When discussing environmental quality, its protection and priorities, surface water quality is mentioned first. This fact shows the importance of water quality for the environmental strategy. In the Action Programme reduction of pollution by urban, industrial wastewater and stormwater is on the top of the list. (*SRL, 1997b*)

The largest environmental financial investments are granted towards the reduction of urban pollution load on surface water. National investments go to building wastewater treatment facilities. The reason for this highest priority is the big amount of discharges of insufficiently treated or even untreated wastewater. Criteria favourable for the investments in wastewater treatment are stability of impact and common efforts. Stability of impact is explained by the fact that during first years of economic decline the reduction in amount and contamination of wastewater was lower compared to the reduction in atmospheric pollution from point sources. Investments from international funds for wastewater treatment make projects more attractive for local funds leading to common efforts to solve the problem. (*RECCEE, 1995*; *SRL, 1997b*)

Kaunas is among five municipalities which have received the national priority investments for improvement of wastewater treatment facilities. Following obligation to the Helsinki Convention the Lithuanian Government assigned the highest priority for expansion/construction of Kaunas, Vilnius, Siauliai (Šiauliai), Klaipeda (Klaipėda) and Palanga municipal wastewater treatment plants. Kaunas was the only city among them which had no municipal wastewater treatment facilities. The Baltic Sea Environmental Action Programme includes Kaunas city among 26 municipalities that need priority investments in municipal and industrial wastewater system (one of the HELCOM priority ‘hot spots’). (*LEPM, 1996a; HELCOM, 1993b*)

Legislative and economic means

Legislative regulation

The Environmental Protection Law was adopted in 1992 and amended in 1996. It is the main law regulating the use of natural resources and environmental protection. All other laws and enactment are adopted on the basis of this law. The Environmental Protection Law regulates public relations in the field of environmental protection, defines the main rights and duties of legal and natural persons preserving biological diversity characteristic to Lithuania, ecological systems and landscape, ensuring healthy and clean environment, rational use of natural resources (article 2 of the law). The law defines competence of all governing institutions, use and registration of natural resources, regulation of economic activities, monitoring system, economic mechanism and control of environmental protection. (*SRL, 1996a*)

The Law on Water was promulgated in 1997. This law regulates the ownership of the internal water bodies, the management, use and protection of their water resources, relations between the owners and users of water bodies, the rights and obligations of persons using water resources (article 1.1). According to the law, water resources and water bodies may be used to supply the population with drinking water, provide medical treatment, recreation, sport, agriculture, industry and other economic activities, navigation, hydropower, fishing, and discharge of wastewater (article 12.1).

The Law on Water includes an article on protection of water from pollution. The law states that wastewater may be discharged into the natural environment only in instances when it does not exceed the limit values for pollution approved by the Environmental Ministry (article 31.1). In designing, constructing and operating economic activities that affect the quality of water, provision should be made for the implementation of measures which ensure a sustainable use of water and protection of water bodies (article 34.2). Legal and natural persons whose economic activities produce an adverse effect on the flora and fauna of water bodies, must compensate for the losses sustained (article 34.9). (*SRL, 1997a*)

The Law on Environmental Impact Assessment (EIA) of the Republic of Lithuania was adopted in 1996. The aim of the law is to provide regulations for the evaluation of a proposed activity that may cause negative impact on the environment and to regulate relationships between parties involved in the process (article 2). The law proposes participants of the EIA process and procedure for initial and full Environmental Impact Assessment. The initial Environmental Impact Assessment is performed in the process of preparation of documents on territorial planning and project proposals to find out if the proposed activity may be carried out in the chosen site. The full Environmental Impact Assessment is performed in the process of preparation of technical projects to identify all potential environmental effects and social aspects and to provide mitigation measures (article 3 and 7.1). (*SRL, 1996b*)

Standards and norms

Standards play an important role in regulation of water pollution and in active promotion of pollution prevention. Water quality standards and wastewater pollution norms set limits for deterioration of water bodies and objectives for water quality improvement. They serve as a target for municipalities and industries to reduce water consumption and contamination of wastewater, because they are related to economic instruments. Taxes on natural resources and taxes on water pollution are calculated according to the standards. (*LEPM, 1996a*)

Water quality standards are set according to the accepted environmental principles. The principles of Best Available Technology and Best Environmental Practice are background for the standards. The final decision about water use and pollution limits is taken after the evaluation of real technical and economic possibilities of municipalities and enterprises for the implementation of standards and the assessment of present state of the environment (*Hägerhäll, B., 1996*). The standards contribute to development of technology. ‘In the case of

Lithuania, a country with economy in transition, environmental standards should be strict in order to prevent flow of outdated technology from Western countries following by further deterioration of environment'(*Andrikis R., 1992*).

Water quality standards are also based on effect on human health and environment. The standards in the form of highest allowable concentration are set after the assessment of possible effect on human health, biota and other elements of surrounding environment. (*SRL, 1997b)*

Standardisation in Lithuania depends on agreements in international community. International conventions such as Convention on Use and Protection of International Watersheds and Lakes ratified by Lithuania and directives of Helsinki Convention (HELCOM) are followed in issuing water quality standards. Recommendations of European Economic Community are also taken into account as Lithuania is striving for a membership in European Union and approximation of the laws is taking place. (*LEPM, 1996a; RECCEE, 1996*)

Sanitary Norms for Human Use of Water HN48 were approved by the Ministry of Health with the consent of the Environmental Protection Ministry in 1994. As the norms were set by the Ministry of Health the main concern is water effect on human health. Water may be used for drinking and other purposes only if it causes no harm to human health. Physical, chemical and bacteriological parameters are determined in the norms regarding water for drinking, bathing, recreation and medical treatment. Sampling operations and inspections of the water are carried out by regional sanitary centres. The enforcement of the norms is rather low, because of lack of analytical equipment in the laboratories, especially in smaller regional centres. (*Hägerhäll B., 1996*)

Surface water quality standards are based on the requirements for fishery. The standards define Highest Allowable Concentration (HAC) that is the upper limit when no distinct harm is caused to fish populations. The standards used in Lithuania are the old standards from the Soviet Union. New standards for surface water quality are under development now and they are planned to be adopted at the end of December 1998. The new standards will include the sanitary norms HN48 presented above, but they will have broader objectives related to human health, human use of surface water as well as the state of natural environment. (*Andrikis R., 1992, Dudutyte Z., 1998*)

There is proposal for new standards to define different level of water quality parameters for different use of fresh water bodies taking into account EU directives 75/440/EEC, 76/160/EEC, 78/659/EEC, 79/923/EEC. While it is impossible to achieve the best quality in all water bodies, it is cost-effective to strive for and maintain such level of water quality that is needed for the exploitation of each water body. Then use-specific water standards are needed. If water is used for recreation higher quality standards should be applied than for fishery. Ecological capacity of the ecosystem should be taken into consideration in defining standards for all water bodies. Specialists from Lithuanian University of Agriculture, Department of Water Engineering suggest to have standards for each of the following surface water categories:

1. household waters
2. shellfish waters
3. fishery waters:
   3.1. salmonid waters
   3.2. cyprinid waters
4. recreation waters

The specialists analyse the need for standards for each of the surface water categories. Even if no surface water is used for household needs for the time being, it is good to have the standards for surface water used for household. Existing sanitary norms for drinking water may be used for this purpose. Water bodies for shellfish farming need to have very strict water quality standards. All Lithuanian water bodies should be suitable for fishery and meeting water quality requirements for fishery is an objective for the nearest future. In the surface waters where salmon is found, stricter requirements should be set up than for waters with fish of carp family. Bathing is suggested to be picked out as the main form of recreation requiring high water quality standards. The standards for bathing should be set up from the point of view of human health. The authors suggest to have these standards as the main objective for water quality management in the long time frame. (*Vycius J. et al., 1997*)

The Wastewater Pollution Norms came into force in 1996. Objectives for the norms are to regulate and to reduce pollution of water bodies with wastewater. The norms are applied for municipal, industrial wastewater, stormwater and mixed wastewater. There are two kinds of wastewater norms: norms for wastewater discharged into surface water bodies and for wastewater discharged into sewerage network.

The norms for wastewater discharged into sewerage network are defined with a concept that wastewater should cause no harm to technological processes in wastewater treatment, use of waste sludge, and the sewerage network. The norms for wastewater discharged into sewerage are less strict than the norms for wastewater discharged into surface waters, because a big part of wastewater is discharged into municipal sewerage without any treatment, e.g. household wastewater. To regulate discharge of industrial wastewater into municipal sewerage network, special norms for industries are issued. (*LEPM, 1996b*).

The norms for wastewater discharged into surface waters are prepared according to Best Environmental Practice and Best Available Technology evaluating the previous soviet norms and directives from international organisations and conventions. They will be reviewed each three years. The norms include not only physical and chemical parameters of the wastewater, but also biological toxicity of the wastewater.

Wastewater norms define Highest Allowable Concentration of contaminants in the emissions (HAC). According to amount of discharged wastewater, Regional Environmental Protection Department sets Highest Allowable Pollution (HAP) limits for all the activities that have negative effect on the environment. Some enterprises lack the technical resources to achieve HAC and HAP (e.g. absence or poor capacity of treatment facilities). Then Temporary Allowable Concentration (TAC) and Temporary Allowable Pollution (TAP) are defined for the enterprises. TAC and TAP are reviewed every year in order to give stronger incentives to reduce concentration of their wastewater. Till now TAP and TAC were used for Kaunas Water Company that is responsible for Kaunas sewerage system, because without any treatment plant it was incapable to achieve national HAC for wastewater. (*RECCEE, 1995*)

Other Lithuanian Environmental Normative Documents (LAND) related to water pollution and use of water resources adopted in 1995 - 1997 are the following:

- Regulations on Urban Stormwater Sewerage and Outlet LAND 3-95
- Norms for Methods for Assessment of Biological Surface Water Pollution LAND 5-95/M-01
- Norms for Use of Wastewater Sludge LAND 20-96

Economic instruments

Economic measures are imposed to induce pollution reduction and prevention, to preserve natural resources. Economic instruments accomplish Polluter Pays Principle that is one of the core-stones in national water resource management. They force enterprises to carry economic responsibility for their environmental actions. New market-based economic instruments were included in Lithuanian environmental policy during last years, because they were not developed in the Soviet Republic of Lithuania. The main economic instruments used now are the following:

- taxes for utilisation of state-owned natural resources
- pollution charges
- credit regulation
- State subsidies
- price policies
- economic sanctions and damage compensation (*SRL, 1996a*)

Taxes for utilisation of state-owned natural resources are imposed on groundwater, surface water, and mineral water. The main objectives of the taxes are to increase the responsibility of the users to use the resource efficiently and to generate financial support for the investigation and preservation of natural resources.

Charges on pollution cover both regulative and economic approaches towards environmental management. Charges are determined according to the degree of deviation from the norms. The two kinds of pollution norms, highest allowable and temporary allowable concentrations were described in the previous section. The pollution taxation system includes waivers. The polluters who implement pollution abatement measures and reduce pollution by more than 25% are exempt from payments up to the investment cost. 70% of collected charges go to the municipal budget, 30% to the national budget. Financial resources of the funds are used for compensation and rehabilitation of the damage to environment, health care, environmental projects, ecological education and other activities. (*RECCEE, 1996*)

Credit regulation is used to follow the investment priority set. State subsidies comprise approximately 2% of the state budget and they are used mainly for the construction of wastewater treatment plants.

All the economic instruments and Polluter Pays Principle do not play as important role as it is expected, because of decreased capacity of polluters. Due to decline in economic activity in the last years, emissions to the environment decreased significantly especially from the industrial sector. Many enterprises do not exceed highest allowable pollution limits. Those who have to pay charges and compensate for the damage are not financially capable sometimes and more strict enforcement measures need to be applied.

Projects concerning water management

Kaunas Water and Environment Project

The city of Kaunas initiated a comprehensive Kaunas Water and Environment Project in order to improve water and wastewater services in 1993. The project involves renovation of water and sewerage networks, upgrading of groundwater well fields, renovation of booster (distribution) stations, the wastewater treatment plant, sewage pumping stations and managerial assistance. (*KWC, 1996*)

Kaunas Water and Environment Project has the largest financial investments with the specific objectives related to water management in Kaunas. The total cost of the project is calculated to be 78.1 million ECU. The project is multilaterally financed by local and international funds. 56.2 million ECU are provided by the Lithuanian Government, the city of Kaunas and cash generated from the operation. Other 21.9 million ECU come from foreign funds: the loan from Nordic Environment Finance Corporation (NEFCO) and the grants from Sweden, Finland and European Union PHARE programme. As a part of this project, a twinning programme between Kaunas Water Company and Stockholm Water Company has been set up, the programme is financed by the Swedish Board for Investment and Technical Support (BITS). (*EBRD, 1996*)

Kaunas Water Company 'Kauno Vandenys' is responsible for implementation of the project. The company is a special status joint stock company fully owned by Kaunas Municipality. Kaunas Water Company manages and operates water supply and wastewater services and the assets assigned to it. The company is in the process of transition from an old state owned enterprise to a business and service oriented water management company. (*KWC, 1996*)

Kaunas Water and Environment Project has been developed based on the Feasibility Study completed in February 1994. The Feasibility Study was carried out by Swedish consultant company K-Konsult Water Projects AB. The study was organised to evaluate the technical state of water and wastewater system and the possibilities of Kaunas Water Company to obtain financial support. The feasibility study reported inefficiency in water supply and sewerage systems, contamination of potable water slightly higher than local standards, high pollution of wastewater. The study proposed activities to rehabilitate Kaunas water and sewerage system and it elaborated an alternative wastewater treatment plant expansion plan. Analysis of financial issues (budget of operation and maintenance), managerial and organisational options for Kaunas Water Company was included in the study. (*K-Konsult, 1994*)

Plans for Kaunas Wastewater Treatment Plant were started in 1990. The site preparation and design were in progress when Kaunas Water and Environment Project was initiated. Kaunas Wastewater Treatment Plant is the main part of the project. The plant is being constructed in two phases: I. mechanical treatment with chemical precipitation for phosphorus and sludge treatment, II. biological treatment with nitrogen removal. The civil works of the first phase are already completed by now. The plant will start operating in June 1999 and by August full operation of the plant is expected. The first stage includes the following main treatment units:

- mechanical bar screens with treatment of screenings,
- aerated grit chambers with treatment of grit,
- primary sedimentation tanks with precipitation for phosphorus,
- facilities for disinfection of the effluent (in the case of epidemics) and outlet to the river,
- anaerobic sludge digestion and mechanical sludge dewatering in centrifuges.

Second phase of the project will be started after the completion of mechanical treatment plant. Then biological treatment with nitrogen removal will be planned and constructed. The biological plant is expected to be finished before 2013. (*K-Konsult, 1993; Rust, 1996*)

Sewerage system is being adapted for the wastewater treatment plant. New sewage pumping stations are being built to direct wastewater flow to the plant. The municipal wastewater outlets will be closed in the end of 1999 and wastewater will be collected at the plant. After treatment the wastewater will be discharged through new outlet downstream the city (figure 1.1). 95% of the total wastewater flow are expected to reach the plant, other 5% contains of urban stormwater that will not be treated. (*Rust, 1996*)

Reduction of wastewater effluents achieved by Kaunas Water and Environment Project and effects on the Nemunas water quality will be discussed later.

Cleaner Production programmes

Cleaner Production programmes are much better environmental opportunity for water management than end-of-pipe solutions such as big wastewater treatment plant. Lower amount of wastewater may be achieved through more efficient water use and internal reuse of water in production processes. Reduction of pollution at source, internal recycling and recovering of materials lead to lower contamination of wastewater following by lower investments in wastewater treatment facilities. Life Cycle Analysis and product development seeking to change the whole process of production, use and disposal interfere impact on environment caused by the product. All these measures may be applied in industry and bring cost effective, 'win-win' solutions for industries improving overall water management in the municipality. (*Lindhqvist T., 1994; Rodhe H., 1993)*

Cleaner Production has not received enough attention in Lithuanian legislation and the support for pollution prevention activities is lacking even if Lithuanian National Environmental Strategy emphasises importance of pollution prevention in the economic activities. Environmental objectives in national economy are the orientation towards low-waste technology, economical use of natural and energy resources, cleaner production. However appropriate national framework and comprehensive cleaner production strategy are absent and they have to be adopted in near future. Further enactment and enforcement of realistic regulations would force and motivate industry to take more account of environmental aspects and consider Cleaner Production actions before investments in end-of-pipe technologies. (*Wangen G., 1996; SRL, 1997b*)

A non-profit organisation Pollution Prevention Centre is active from 1994. The centre promotes sustainable development, cleaner production / pollution prevention / waste minimisation in Lithuanian industry and other spheres of economy. The centre provides technical information and assistance to local industries that promote industrial process change, resulting in reduced waste generation and emissions to the environment, as well as cost savings for industries. The Pollution Prevention Centre trains specialists who could deal with questions of cleaner production and it organises different seminars and workshops. (*Staniskis J., 1996*)

Different Cleaner Production programmes have been held in Kaunas. Most of them were joint projects between Lithuanian and Danish, Swedish, Norwegian or Dutch specialists. Some of the projects are listed below.

- Waste Minimisation Opportunity Audits to Introduce Cleaner Technologies in Lithuanian Industry
- Waste Minimisation Programme launched by World Environmental Centre
- Capacity Building in Cleaner Production in Industry in the Baltic Countries, St. Petersburg and Kaliningrad area
- Implementation of Cleaner Production Projects in Lithuanian Textile Industry

The need to support Waste Minimisation activities was stressed in the recommendations adopted by the UNEP IE Cleaner Production expert seminar held in Kaunas in 1994. Governments and local authorities in Central and Eastern Europe (CEE) countries were requested to support Waste Minimisation activities in their economic and industrial policies, and especially to refrain from maintaining high subsidies on energy, raw materials and waste disposal. Governments and international organisations were requested to make funds available for financing low cost Waste Minimisation investments by industry. One of the recommendations had a direct reference to wastewater treatment plants when it was stated officially that investments in high cost, end-of-pipe, cleaning facilities in companies and in municipalities should not be supported without prior Waste Minimisation programmes being performed. (*Lindhqvist T., 1994*)

Cleaner Production programmes are dealing with different environmental questions in production processes and water is only one of them. Most of the pollution prevention projects organised so far were aiming more at a reduction of emissions to the air and solid waste minimisation than at a reduction of wastewater contamination. However, the projects introducing better housekeeping practices and more efficient use of raw materials reduce consumption of water, amount of wastewater and concentration of wastewater. This leads to lower pollution load on the river.

Healthy Cities Project

Kaunas city is a member of the Healthy Cities Project. The Healthy Cities Project is founded by WHO EURO and it involves more than 35 cities in Europe. One of the ideas of Healthy Cities is co-operation of health and environmental organisations and institutions. The objective of the project is to achieve improvement in population health through better environment and strengthened human health. The Kaunas Healthy Cities Project organises different research and management programmes.

Till now water pollution has not received enough attention in the Kaunas Healthy Cities Project. Effect of atmospheric pollution on health and on infant mortality, healthy lifestyle of citizens, healthy food and health promotion programmes were developed. The only water related project carried out is an Assessment of Bacteriological Pollution in Kaunas Reservoir, the Nemunas and the Neris in Kaunas City Area. The assessment is a part of municipal ecological monitoring that is described in the following surface water monitoring section. (*Kameneckas J., 1996*)

Water monitoring

Water monitoring in Kaunas city zone consists of surface water quality monitoring carried out by Joint Research Centre and Public Health Centre and wastewater monitoring carried out by Kaunas Water Company.

Surface water monitoring

Joint Research Centres Kaunas Regional Department is holding a regular surface water monitoring as a part of the Lithuanian Environmental Monitoring Programme. The objectives of the monitoring are to observe surface water quality and to evaluate tendencies of change. There are four monitoring points in Kaunas city area:

1. in the Nemunas upstream Kaunas city downstream the dam
2. in the Nemunas downstream Kaunas at the right bank
3. in the Nemunas downstream Kaunas at the left bank
4. in the Neris river upstream confluence with the Nemunas

Downstream Kaunas water quality is measured at both sides, because after the discharge of wastewater, pollutants do not mix properly before the monitoring point and water at the left bank is usually much more polluted. The monitoring points at the Nemunas river are displayed in figure 1.1.

58 physical, chemical and bacteriological parameters are monitored. Physical (water flow, temperature, turbidity), basic chemical characteristics (BOD_7, NH_4, NO_2, NO_3, total N, PO_4, total P) are measured once every month. Metals, pesticides and bacteriological parameters are measured 2 - 4 times a year.

National Hydrobiological Laboratory monitors hydrobiological state of surface water bodies. They measure fito-plankton, zoo-plankton, zoo-benthos and perifiton. Hydrobiological monitoring is separated from surface water quality monitoring. The data are not published and they are not available for the author.

Monitoring of fish and other higher organisms is not performed in the Nemunas regularly. Single studies of the state of the fisheries are organised by corresponding research institutes.

Kaunas Public Health Centre executes surface water monitoring as a part of municipal ecological monitoring. The objectives of Kaunas municipal ecological monitoring are assessment of the living environment in order to identify effects of polluted environment on human health. Pollution of surface water may affect human health through infiltration of pollutants to groundwater reservoirs and during bathing in the water bodies.

Surface water quality is measured at the groundwater well fields where it may affect potable water quality. There are four monitoring points at Kaunas groundwater reservoirs:

1. in Kaunas reservoir
2. in the Nemunas upstream Kaunas downstream the dam
3. in the Neris river upstream Kaunas
4. in the Neris river channel

and two points downstream the city:

5. by Marvele (left bank, near the main outlet of wastewater)
6. by Lampedziai (right bank, not far from new groundwater well field)

The programme is run since 1993. Measurements were done every season 3 - 4 days in succession 3 times per day. Later programme was limited. In 1997 and 1998 measurements were done only in months of April and June respectively. Every time main physical (temperature, turbidity), chemical (pH, BOD_7, NO_2, NO_3, Fe) parameters and bacteriological parameters (total coliforms, fecal coliforms, E. coli) are monitored. (*Eicinaite R. et al., 1995; Kligys G. et al., 1996*)

Assessment of water quality in the beaches in Kaunas city zone is organised by Kaunas Public Health Centres Section on Hygiene in the Living Environment. Their mane focus is level of health risk for bathing in the surface water bodies. Possible beach areas within Kaunas city limits are shown in figure 1.1. Beaches' water quality monitoring is executed in 7 possible beach areas:

1. in the beach of Kaunas reservoir
2. in Lampedziai reservoir

3. - 5. two beaches in the Nemunas river in Kaunas city area

6. - 7. three beaches downstream Kaunas

The beaches monitoring data are reported only for year 1997 and 1998. Measurements are usually done during warm season of the year (from May to August) every month. Assessment of the beaches downstream Kaunas is executed only once (1997 July). Together with main physical and chemical parameters, bacteriological pollution is measured.

Wastewater monitoring

Kaunas wastewater monitoring includes monitoring of municipal wastewater at outlets to the river and monitoring of industrial wastewater.

Municipal wastewater is monitored by Kaunas Water Company. Environmental Protection Agency under the jurisdiction of Kaunas Regional Department controls the company. Kaunas Water Company monitors wastewater quality before discharge into the river. The monitoring is executed once a month. Main physical (water flow, temperature) and chemical parameters (pH, BOD_7, NH_4, NO_2, NO_3, total N, total P, heavy metals, oil products and detergents) are measured.

Industrial wastewater from industries that consume more than $50m^3$ water per day is monitored by Kaunas Water Company. There are about 120 such industries in Kaunas. Frequency and parameters measured are defined by the agreement between an industry and the company. They are monitored between once a month to once a season. The parameters above all include BOD_7, suspended solids, metals, oil products, detergents. Large industrial enterprises have chemical laboratories and they measure their wastewater contamination. (*SV, 1997a*)

III. MANAGEMENT RESULTS IN URBAN LOAD REDUCTION

Wastewater reduction

Amount of wastewater from Kaunas city has decreased significantly over the last years. In 1997 total amount of wastewater discharged into the river was more than 50% lower than in 1991. Wastewater production was decreasing all the period from 1991 to 1997 continuously, except 9% increase in 1993 following a big 26% decrease in 1992. Amount of wastewater per year is shown in figure 3.1.

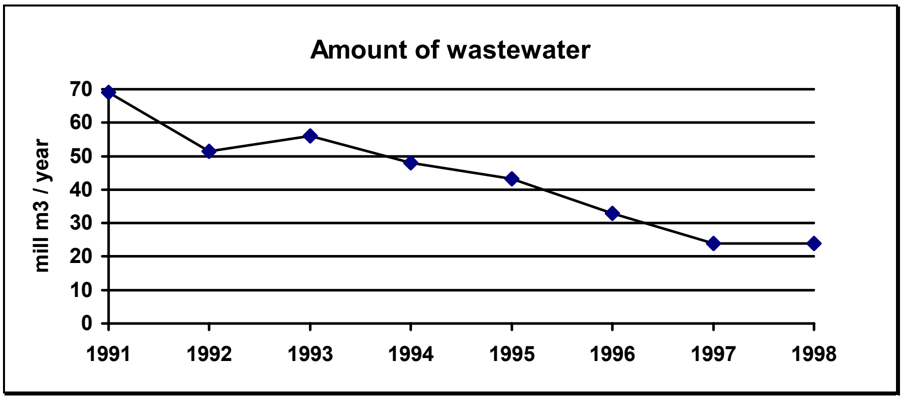


Figure 3.1. Kaunas Wastewater production in 1991 - 1998. (Data source - Kaunas Water Company)

Figure 3.1 shows that wastewater production stabilises. Preliminary data for 1998 predict amount of wastewater to be similar to the amount in 1997.

Amount of pollutants discharged into the river through Kaunas wastewater decreased since 1991. Concentration of suspended solids and oxygen consuming substances (measured as BOD) follows the reduction pattern of wastewater production. In 1997 BOD_7 was higher than in 1996 indicating higher pollution with organic material. Increase in pollution of the wastewater happens because of higher production of industrial wastewater. Kaunas wastewater organic pollution load in 1991 - 1997 is shown in figure 3.2.

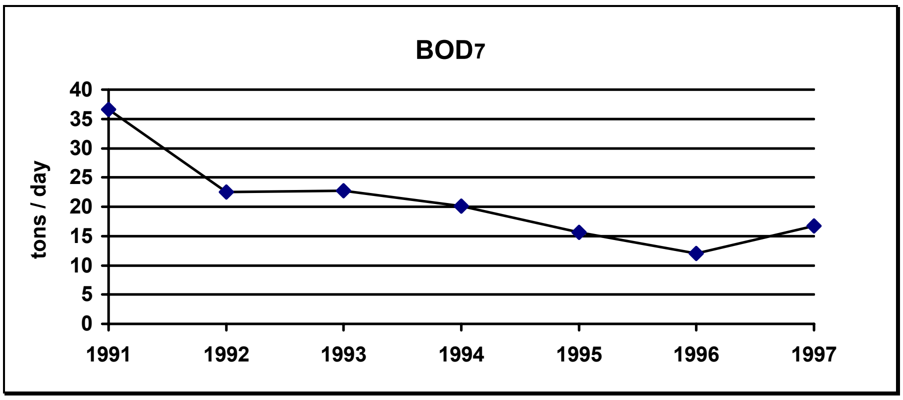


Figure 3.2. Biochemical oxygen demand (BOD_7) of Kaunas wastewater in 1991 - 1997. (Data source - Kaunas Water Company)

Concentration of other pollutants does not follow the pattern of BOD_7 and much stronger fluctuations of their concentration are observed. For example, concentration of nitrogen was increasing from 1991 to 1994, then it decreased by 17% in 1995 and increased thereafter.

Concentration of heavy metals shows general decrease through the period, but temporal increase during some years is observed. Pollution load of total nitrogen and some of the heavy metals are displayed in figures 3.3 and 3.4.

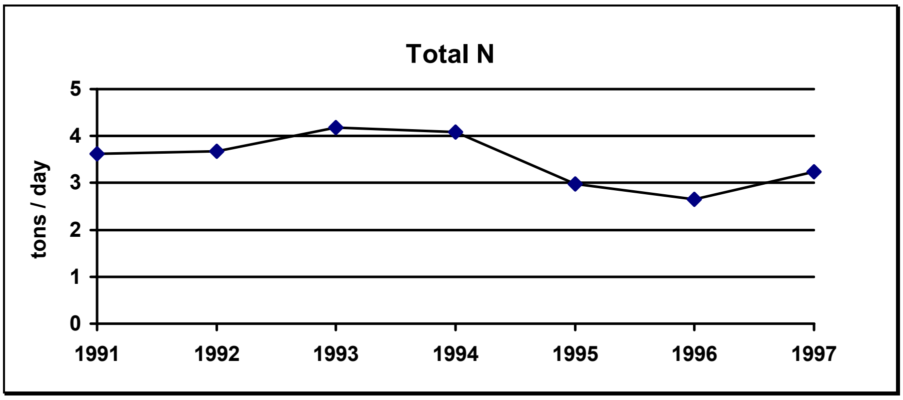


Figure 3.3. Total nitrogen pollution load in Kaunas wastewater 1991 - 1997. (Data source - Kaunas Water Company)

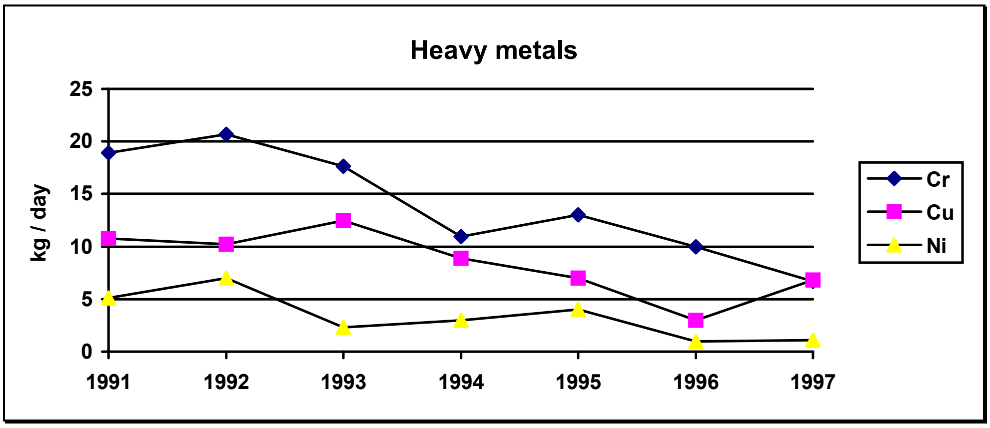


Figure 3.4. Heavy metals' pollution load in Kaunas wastewater 1991 - 1997. (Data source - Kaunas Water Company)

The bacteriological pollution of the wastewater is not monitored and changes in amount of coliform bacteria or other indicators of bacteriological pollution are not registered.

The conclusion could be drawn that pollution load was decreasing from 1991 to 1996 in general. Pollution by some contaminants increased in 1997.

Factors for wastewater reduction

The new environmental legislation expressed importance of water questions and changing attitude towards water. Earlier high consumption of water was an indicator for development and for good hygiene practice. The increase in consumption per capita was encouraged. Water was almost a free resource and no price mechanisms limited water use. Water is not a free resource for consumption any more. Now water is understood as a limiting resource in means of quality and quantity which has to be used in a proper, sustainable way. Water is also a part of our living environment that has to be protected from adverse effects caused by inadequate management.

Domestic wastewater

Amount of domestic wastewater decreased as a consequence of lower water consumption. There is direct dependence of amount of wastewater upon consumed potable water in households. There is no information available on changes in domestic wastewater quality, but according to practice, general domestic wastewater pollution load slightly decreases with reduced amount of produced wastewater.

Domestic water consumption and wastewater production decreased due to an increase in price and a possibility to pay according to the amount consumed. Average domestic water consumption reduced from maximum of 266 litres per person and day in 1988 to about 190 litres per person and day in 1996 in Kaunas.

Economic changes in Lithuania led to the increase in water prices. After the restoration of Lithuanian independence and reorganisation from plan economy to market economy subsidies for water were reduced gradually and Kaunas Water Company had to cover more and more of its expenditures by income from customers. Water consumers had to pay real price for potable water and wastewater services. Water prices increased. Recession in national economy, higher prices for energy and raw material increased water service costs for the water company. This increase had to be also covered by customers. Water and wastewater prices for domestic consumption increased from 0.13Lt/m^3 to 2.88Lt/m^3 (1Lt = 0.25US$) in Kaunas in last five years, inflation through this period was about 160%.

People became more interested in water saving. Because of national economic problems, population incomes were increasing at much lower rate than price for public services. The share of incomes which people had to pay for water and wastewater increased. People became willing to save water and pay accordingly to consumed amount. In 1992 only 26 619 people out of 355 620 people served with water had private water meters in their villas or apartments and paid according to their reading. Other inhabitants had meters for whole apartment block with an average of 79.2 people per connection. Only 72% of the meters were in working order and majority of people did not pay for water according to what they had consumed. According to the Water Saving Study, from 1992 to 1996 amount of meters in villas and private apartments increased from 9 740 to 11 500. Installation of water meters was also encouraged by the municipality. Kaunas municipality paid the cost for installation of the meter for big families. (*K-Konsult, 1993; SV, 1997c*)

The data presented above seem to be contradictory. Average domestic water consumption per person decreased by almost 30% from 1992 to 1996 while population served with private meters increased from 7.5% to about 8.7%. If only 8.7% of population have private meters and pay according to the consumption, total domestic water consumption can not decrease by 30% (population is served with water continuously). As there are no other important factors for the water and wastewater reduction except metering and saving, the conclusion is that the presented data are not reliable.

The causes of wastewater reduction described above are presented in full diagram in figure 3.5.

Domestic consumption of water and production of wastewater is proposed to stabilise at the level of 160 litres per person and day in summer 1999. Due to factors described below amount of water is predicted to remain at this level in the near future. These 160 litre per person and day are seen as a goal for Kaunas Water Company.

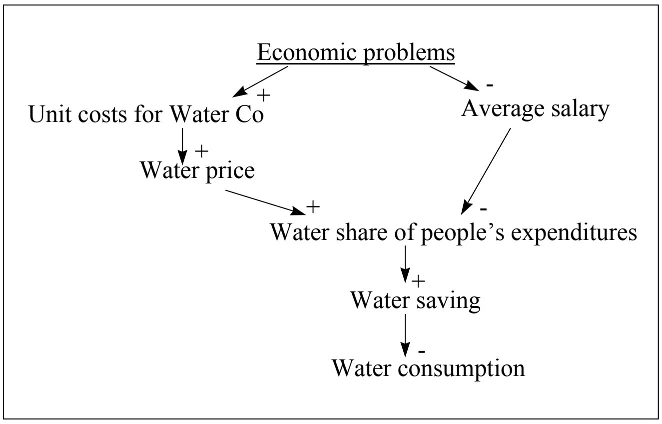


Figure 3.5. Diagram of factors for domestic wastewater reduction.

Note: '+' means that increase in a cause leads to increase in an effect or decrease in a cause leads to decrease in an effect;
'-' means that increase in a cause leads to a decrease in an effect or decrease in a cause leads to increase in an effect.

Water saving causes an increase in water prices. Low amount of water consumed and wastewater produced are not favourable for the company which provides the services. Water flushing needed to prevent clogging of pipes when consumption reduces, and high fixed maintenance costs of sewerage and water supply systems keep high costs of water company even with reduced demand of water. Water company has to cover all the costs. Water prices increase further. (*SV, 1997c*)

Because of increase in costs, installation of new meters should decrease in the future. Water Savings Study issued as a part of Kaunas Water and Environment Project recommended to stop promotion to install new meters. The part of society that was willing to save water has already installed water meters and those who were waiting until now most likely will not put effort to get a device later. If less new meters are installed, potential for further wastewater reduction diminishes.

The price for water as a driving force for the reduction of wastewater is not important any more. During last few years, inflation decreased in Lithuania. Population capacity to pay for the basic needs increased. Even if water prices are rising slowly, their share in population expenditures does not increase. People already do save water and water prices do not encourage people to save water more. The stabilisation mechanism is displayed in figure 3.6.

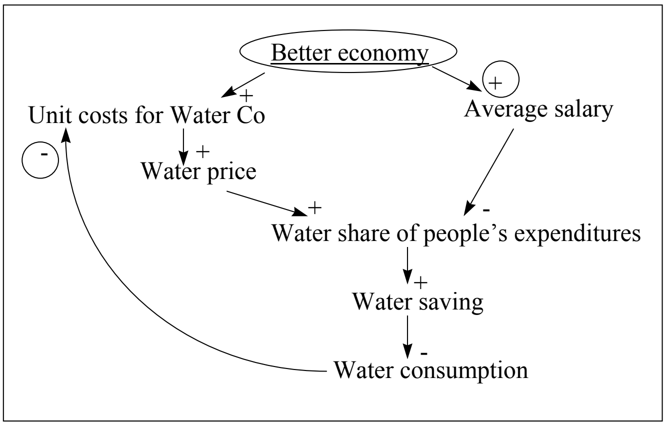


Figure 3.6. Diagram of factors for domestic wastewater stabilisation. (See note after figure 3.5.)

Industrial wastewater

There are two main factors for industrial wastewater reduction: economic incentives and general economic recession. Measures, giving economic incentives, e.g. pollution charges, proper water price and Cleaner Production practices are positive actors providing incentives for constant reduction in wastewater pollution. Recession of national economy that was evident in Lithuania in 1992 - 1996 was negative in general, but it reduced amount and contamination of wastewater temporarily.

Total amount of Kaunas industrial wastewater reduced from about 23 million m^3 in 1993 to 14 million m^3 in 1996.

All sources of literature indicate economic incentives and decline in production as factors for industrial wastewater reduction, but no one of them defines to which extent each factor affects wastewater pollution load. This task is difficult, because industries are not willing to show how much their economic activities have declined, on the contrary, the whole country and industries themselves try to report the best indicators approving good condition of their production.

Through economic instruments wastewater pollution is related to the profit. Higher production gives higher profit, but it also produces more wastewater. It leads to higher expenditure for pollution charges and consumed water. The way to reduce these costs is to apply cleaner production and to prevent pollution, to reduce water consumption. When consumers are interested in ecological products, the company can gain advantage in market share due to applied cleaner production practices. The basic diagram of incentives for industrial wastewater reduction is shown in figure 3.7.

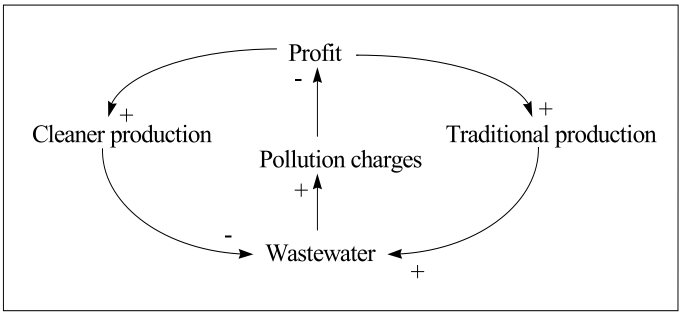


Figure 3.7. The diagram of factors for industrial wastewater reduction. (See note after figure 3.5.)

Various economic instruments give incentives for industries to reduce amount and contamination of wastewater. Increase in water and wastewater prices stimulates industries to reduce water consumption and wastewater production. State subsidies for water are eliminated almost for all types of industries and producers have to pay full price for water services that is higher than it used to be earlier. Pollution charges affect concentration of wastewater. The charges are based on effluent norms that are defined for each industry taking into consideration its technological capacity to prevent or to treat wastewater. The norms are reviewed every year and they become stricter in order to motivate industry to look for new possibilities to reduce pollution. Environmental Impact Assessment is applied for new objects forcing new industries to look for best solutions and best environmental practice.

Cleaner Production programmes are organised to introduce better practices and technologies to prevent pollution at source. Such an example is the project of environmental impact minimisation at the tannery JSC Vilkas in Kaunas. Within the frame of the project water re-circulation scheme in the primary processing of the wool skins was developed which achieved reduction of water consumption and wastewater production, and lower amount of heavy metals, especially chromium, in the wastewater. According to the scheme, the project brought economic benefits for the tannery with savings of about 600US$ per day and investments pay back period of 7 months due to savings in energy, reduced charges and chemicals' savings. (*Grigauskas R., 1996*)

The economic recession a caused general decrease in economic activity as well as the decrease in wastewater production. The most sudden decline in economic activity was in 1992. It was noticed in total amount of Kaunas wastewater that was by 26% lower than the year before (figure 3.1). The sudden drop was caused by economic blockade from Russia that stopped providing Lithuania with oil and other basic raw materials for industry. General decline in production was caused by lost market in former Soviet Union, more expensive raw materials, energy and also water. Many industries worked at lower capacity and some production lines were closed totally which was followed by lower consumption of water and production of wastewater.

During the last few years wastewater production is increasing, because industrial activity has started to recover. According to the data from Kaunas Water Company, amount of industrial wastewater has increased by 20% in some industries. Companies find new market and new possibilities for management. The products for export to western countries have to follow the strict environmental requirements that include wastewater discharge. Because of cleaner technologies and positive economic instruments, concentration of pollutants in industrial wastewater does not increase as quickly as amount of the wastewater.

Wastewater load in the future

Kaunas wastewater pollution load to the river will decrease significantly when the wastewater treatment plant starts to operate. Then concentration of discharged wastewater will be defined by the efficiency of the plant.

Kaunas Wastewater Treatment Plant mechanical treatment with chemical phosphorus precipitation is expected to start operating at full capacity in August 1999. The main effluent standards expected in the first stage are shown in table 3.1. Concentration of pollutants in discharged wastewater will be lower or equal the standards. The plant in the first stage will reduce load of organic material by 60%. Concentration of phosphorus will be reduced by almost 70% and it is expected to be 1.5mg/l in the treated wastewater. Nitrogen removal will be possible only after construction of biological treatment. During the process of direct precipitation bacterial reduction of over 90% will be obtained. Through removal of suspended solids, 70 - 80% of heavy metals (nickel only 30 - 40%) will be removed. (*K-Konsult, 1993; Rust, 1996*)

Table 3.1. Pollutants in Kaunas wastewater in 1997 and expected standards after mechanical treatment with phosphorus precipitation (stage I), and after biological treatment (stage II). Concentrations in mg/l. (Data source: Kaunas Water Company)

Parameter	1997	Stage I	Stage II
Suspended solids	158	30	17
BOD_7	180	80	17
Total P	4.59	1.5	1.5
Total N	34.9	40	12^S or 25^W

Note: ^{S} - summertime; ^{W} - wintertime.

Biological treatment in Kaunas is expected to be added before 2013. According to preliminary calculations, the biological treatment plant will remove 91% of organic matter and suspended solids load in the wastewater. Reduction of nitrogen is expected to be 65% in summertime and 29% in wintertime (because of different level of the activity of the organisms). Effluent standards for the second stage are shown in table 3.1. above. (*K-Konsult, 1993*)

The Wastewater Treatment Plant does not have specific objectives to remove metals from the wastewater, furthermore, heavy metals are hazardous for biological treatment and unfavourable for use of wastewater sludge. Industries are forced to implement pollution prevention at source or pre-treatment facilities in order to fulfil stringer requirements for heavy metals in wastewater. If concentration of heavy metals does not increase norms in wastewater, wastewater sludge is planned to be used for growing biological forest for energy needs. According to calculations based on heavy metal's concentration in Kaunas wastewater in 1996, wastewater sludge will easily fulfil European Union requirements and can be used for biological forest or agriculture. (*SV, 1997b*)

River water quality in the future

Water quality in the Nemunas river is affected by two independent factors, urban wastewater and the Neris river load. No clear trend in changes in the Nemunas river water quality downstream Kaunas in 1993 - 1997 can be identified. Even if wastewater pollution load reduced by some parameters before 1997, water quality downstream Kaunas did not change distinctly.

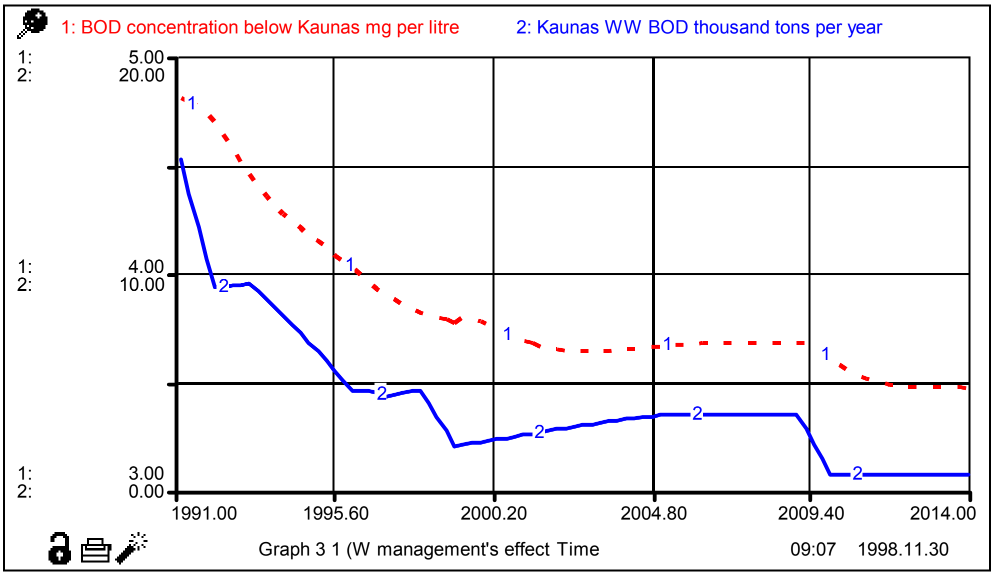
Water management in Kaunas city can change water quality downstream Kaunas only by big reduction in wastewater pollution load. The Neris river pollution is considered as an external factor when analysing Kaunas effect on the Nemunas water quality.

Model A: Effect of the wastewater management on water quality in the river

Effect of amount and contamination of Kaunas wastewater on water quality in the Nemunas river was analysed by an example of BOD_7. Average values of BOD_7 in the Nemunas river upstream Kaunas, in the tributary Neris before the confluence and in the tributary Nevezis before the confluence from 1994 - 1997 were used. Pollution in the rivers upstream Kaunas was assumed to be stable in order to identify effect of the urban wastewater. Until 1999 the data from Kaunas Water Company on BOD load originating from Kaunas wastewater were used. Concentration of BOD which is expected to be in the treated wastewater was used for the prediction of future BOD load. Effect of the biological wastewater treatment is shown starting from the year 2010. The results are presented in graph 3.1.

According to the results of the model, BOD concentration in the Nemunas river below Kaunas decreases from 4.81 to 3.79mg/l in the period 1991 - 1998 due to reduction in amount and contamination of the wastewater. BOD concentration in the river stabilises before 1999, because of stabilisation in production of the wastewater. Opening of the treatment plant reduces BOD concentration to 3.64mg/l. If amount of wastewater increases by 46% in the future due to higher industrial production and it reaches the level of 1995 in 2005, then BOD in the river will increase to 3.68mg/l (the increase in BOD in the river is small due to the treatment plant). The biological wastewater treatment will reduce BOD in the river to 3.47mg/l.

The model shows that effect of the wastewater on the river water quality decreased very much in the last eight years. The effect of wastewater would increase after 1999 if the treatment plant did not start to operate. An increase in production of the wastewater by 46% will increase BOD in the river only by 1% when the municipal treatment is working. The effect on BOD concentration in the river caused by the mechanical and biological treatment will be lower than the effect caused by economic recession and by incentives to reduce wastewater pollution, but when economic situation becomes better, economic incentives alone are not efficient enough to reduce the negative effect of the wastewater and the treatment is needed especially now in order to reduce the negative effect further.



Graph 3.1. Effect of management on Kaunas wastewater load and on the water quality in the river.

Note: BOD_7 concentration in the Nemunas river downstream of Kaunas city (line Nr.1) is expressed in mgO_2/litre. BOD_7 load in Kaunas wastewater before the treatment (line Nr.2) is expressed in thousand tons of BOD_7 per year.

There are a few researches done on water quality improvement after opening Kaunas Wastewater Treatment Plant in Kaunas University of Technology. V. Vinceviciene simulated model for water quality management in the Nemunas river basin. She investigated impact of Kaunas Wastewater Treatment Plant on the river water BOD, NH_3, organic phosphorus and dissolved phosphorus. For the simulation she used average annual monitoring data from Joint Research Centre Kaunas Regional Department from the period 1982 - 1991. For scenario with working treatment plant treated effluent standards were higher than are expected now (e.g. $5mgO_2$/l for BOD_5, 20mg/l for total N). The model is one-dimensional with first order differential equations for material transport and chemical transformation of materials. Simulation of the model showed almost 10% decrease in concentration of oxygen consuming substances, 2.5% decrease in ammonia concentration, about 10% decrease in organic phosphorus and about 5% decrease in dissolved phosphorus downstream the city with working regime of the plant. As used effluent concentration was lower and amount of wastewater higher than is expected now, similar results can be in the real situation. The model also showed that 2/3 of the increase in organic material downstream the city is determined by the Neris river pollution load and 1/3 of the increase by the urban wastewater. (*Vinceviciene V., 1996; Staniskis J. et al., 1996*)

Statistical evaluation of impact of Kaunas wastewater on the quality of the Nemunas river was analysed by V. Jurjoniene and E. Valatka. They calculated main water quality parameters after full mixing of the wastewater with the Neris river load and the Nemunas water. Concentration of the following parameters was investigated: suspended solids, BOD_7, total N, total P, oil products, chromium, nickel, zinc and copper. Two data sets were used: 1) annual average concentrations from 1991, 2) annual average concentrations from 1995. Three scenarios for every data set were investigated: a) discharge of untreated wastewater, b) discharge of mechanically treated wastewater, c) mechanically and biologically treated wastewater. Effluent standards used for the treatment were very similar to the latest standards. BOD_7 in the river without wastewater treatment was $7.31mgO_2$/l and $5.94mgO_2$/l for the data from 1991 and 1995 respectively. Calculated BOD_7 reduction was between $6.34mgO_2$/l and $5.73mgO_2$/l for mechanical treatment and 5.19 - $5.13mgO_2$/l for biological treatment. Concentration of total nitrogen in the river without wastewater treatment was 2.26 - 2.01mg/l.

It was calculated to be 2.19 - 1.98mg/l for mechanical treatment and 1.83 - 1.78mg/l for biological treatment. (*Jurjoniene V. et al., 1997*)

The wastewater treatment will reduce bacteriological pollution load discharged into the river. Because of that, bacteriological pollution in the rivers is expected to decrease. Reduction of bacteriological pollution was investigated with help of *Stella model*. Simulation of the model showed that 95% reduction of bacteriological pollution during the first stage of the treatment plant will not reduce bacteriological pollution in the Nemunas below standards. Lithuanian standards will be reached only after the opening of biological treatment. The model is described more detailed in the section Impacts and Benefits for Human Welfare below.

In summary, Kaunas wastewater treatment plant improves water quality in the Nemunas downstream the city to a limited extent. After opening mechanical and biological treatment oxygen consuming substances will still exceed highest allowable concentration (2.3 mgO_2/l). Nitrogen concentration will be reduced till surface water standards when biological treatment is adopted. Average phosphorus concentration does not exceed HAC now, but chemical precipitation for phosphorus will reduce summer peaks till allowable concentrations.

The changes in effect of the Neris are neglected in the analysis of the Nemunas water quality in the future, because only pollution originating in Kaunas city is considered. But it was proved earlier, that the Neris has high effect on the Nemunas water quality. It means that further improvement in the Nemunas can be done reducing pollution in the Neris. This reduction may be achieved due to better wastewater management and more efficient wastewater treatment in Vilnius city and due to decrease of agricultural runoff.

IV. ANALYSIS OF ENVIRONMENTAL AND SOCIAL IMPACT

The previous chapter analyses gains of water management in Kaunas city to reduce wastewater pollution and to improve water quality in the river. But urban wastewater does not affect only chemical characteristics of the river water, it has secondary effect on aquatic organisms, the river ecosystem and social environment that is closely related to surrounding natural environment. Water management in the city, if organised in proper prudent way, may reduce the environmental and social impact and be beneficial to the river ecosystem and local population.

This chapter identifies and analyses environmental and social impact of Kaunas wastewater. Priority of the water pollution problem in the national environmental strategy is proved before, but are the strategy and legislation concerned about social and environmental benefits? What is the role of the environmental impact assessment in water management? What effects on the river ecosystem and population do water pollution cause? Have the negative effects been reduced by water management practices in Kaunas city? The following analysis looks for an answer to these questions.

Environmental and social objectives in legislation

The objectives of the National Environmental Strategy for the year 1996 - 2000 are:

- to ensure sustainable use of natural resources
- to preserve biological and landscape diversity
- to maintain proper human life conditions

The objectives proclaim incentives to preserve environment, natural resources and to seek human welfare, but they are very general. The strategy does not define them more explicitly. Their application into practice is not explained. The need for clearer definition of goals and principles as well as for orientation towards long-term goals of environmental legislation is expressed already in the Strategy (article 6.1). (*SRL, 1997b*).

The Strategy includes detailed action programme, but it does not give an explanation why the actions should be taken except from those general objectives written above. The investment priorities granted towards Kaunas Wastewater Treatment Plant are based on the wastewater pollution load and bad river water quality downstream the city not analysing impacts of water management on the environment in a broad sense. In all the official reports approving need for the wastewater plant, only the chemical parameters of Kaunas wastewater are given. The difference in the Nemunas water quality upstream and downstream the city is reported as the only consequence of the wastewater discharge forgetting the Neris river pollution load. All the reporters take for granted that wastewater causes a negative impact on the environment and they think that the design of a wastewater treatment plant does not require further assessment of environmental impact.

The Environmental Protection Law has a systematic view towards environment. The environment is defined as the whole of mutually related elements functioning in nature (the earth's surface and underground, air, water, soil, flora, fauna, organic and inorganic material, anthropogenic components) as well as the natural and anthropogenic systems uniting them (article 1). According to the law, environmental protection includes protection of the environment from all negative effects, physical, chemical, biological, etc. (article 1). This principle gives the legislative background that the Nemunas river should be protected not only from chemical effect on water quality, but also from impact on living organisms in the ecosystem. (*SRL, 1996a*)

The purpose of the Lithuanian Law on Water is to regulate relations of water users guaranteeing sustainable use of water resources. Relations pertaining to the use of water resources are regulated by taking into account first the creation of conditions necessary to meet the needs of the economy and population. Basic need of drinking water is considered to be of the highest priority among all water uses. The use of surface and ground water resources has to be in a sustainable manner using the resources efficiently, preventing them from deterioration and striving for improvement of their general condition (articles 1.2, 12.2). (*SRL, 1997a*)

The Law on Water defines water resources as water content of the body (article 3.11), but the law states also that water use should not be harmful to other parts of the surrounding environment such as ground and biota. Water resources are defined as 'quantitatively estimated water in surface and ground water bodies, located in a specific area'(article 3.19). The surrounding environment of water is protected from negative effect by duties of users of water resources who 'must not cause any harm to the landscape and its elements (terrain, soil, flora, fauna) and earth entrails' (article 10.1.6). Economic activities in the water bodies have to be organised in such a way as to minimise the adverse effects on flora and fauna (article 34.1). (*SRL, 1997a*)

In summary, the environmental legislation in Lithuania has a basic objective to reduce all kinds of environmental impacts caused by the use of water resources.

The need to evaluate the impact on environment of a proposed activity is defined by the Law on Environmental Impact Assessment (EIA). The law and regulations supplementing it describe a comprehensive procedure for EIA. During the Environmental Impact Assessment every direct and indirect, complex, temporal and constant, reversible and irreversible, positive and negative impact should be examined. Different solutions to reduce negative effects should be listed. The assessment of the impact on quality of water bodies, flora and fauna, human health and the assessment of the impact on social - economic, cultural - ethnic conditions are a part of EIA. The list of economic activities and objects that are obliged to perform EIA was adopted in May 1997 by the Government. According to the list wastewater treatment plants have to organise EIA. (*SRL, 1996b*)

Lack of Environmental Impact Assessment for Kaunas Wastewater Treatment Plant

An Environmental Impacts Assessment was not developed for Kaunas Wastewater Treatment Plant. Project for the plant was started in 1990 and no Environmental Impact Assessment was performed then. Rules on EIA came into force only 6 years later.

The Feasibility Study for Kaunas Water and Environment Project carried in 1994 refers to a few environmental effects caused by Kaunas wastewater. The study includes calculated addition of pollutants to the river from Kaunas. Because of increase in pollutants' concentration, the following environmental effects are mentioned:

- eutrophication with an excessive growth of algae and weeds
- possible disturbance of fish life and injuries on fish food organisms due to low amount of dissolved oxygen
- detrimental effect of ammonia for the fish life
- risk for waterborne diseases due to presence of pathogenic bacteria
- closing of adjacent beaches during summer season due to high bacteriological pollution
- effect of bacteriological pollution and metals on quality of the groundwater which is infiltrated from the river

- impact of nutrients and heavy metals on coastal zones of the Curonian Lagoon and the Baltic Sea (*K-Konsult, 1994*)

These effects are mentioned very briefly referring to general changes in ecosystem caused by changes in water quality. The extent of the impact caused by polluted Kaunas wastewater and the impact specific for the local situation around Kaunas city are not analysed. The positive effect on fisheries, the reduction in eutrophication and in human health risk due to the applied wastewater treatment are not calculated. The impact of the different technological solutions and suggestions for water management based on the impacts are absent in this study too.

Concluding the overview of the brief description of environmental impact it should be admitted that the Feasibility Study prepared listed almost all the most important effects on the river ecosystem and people, but a comprehensive assessment of the effects is lacking until now. The following section analyses impact on the Nemunas ecosystem that were mentioned, but not elaborated in the Feasibility Study.

Kaunas wastewater impact on river ecosystem

The discharge of the contaminated urban wastewater increases pollution in the river and causes negative impact on aquatic ecosystem. The most severe ecological problems in the Nemunas downstream Kaunas are eutrophication and reduced biodiversity.

Eutrophication

The Nemunas river is eutrophicated all the way to delta and the most oppressive eutrophication is registered downstream the discharges of urban effluents and the inflow of eutrophicated tributaries that bring a high amount of nutrients. Untreated Kaunas wastewater acts as an eutrophication potential for the Nemunas. The Neris river is more eutrophicated than the Nemunas upstream Kaunas. It is proved earlier that the Neris nutrient pollution load is higher than that of the wastewater, it means that the Neris bears higher responsibility for the eutrophication downstream the city. However, the pollution load of the wastewater is big enough to put considerable pressure in addition to the Neris load. Eutrophication begins when the water warms up. Kaunas wastewater effect is seen especially in spring when temperature of wastewater is a little bit higher than water in the rivers and growth of algae (eutrophication) is stimulated earlier in spring close to the outlets of the wastewater.

Kaunas wastewater is responsible for about 1/3 of the increase in concentration of nitrogen, phosphorus and oxygen consuming substances downstream the city. The same proportion may be used for the rough assessment of the extent of eutrophication caused by the wastewater.

Biological diversity

Biological diversity in ecosystem is directly dependent on chemical quality of water. For example, during eutrophication (which is a consequence of an extreme amount of nutrients) a few algae species are abundant while others may become totally extinct. When water quality deteriorates, species sensitive to higher concentration of contaminants disappear gradually or degenerate. During an intensive decay of organic material (followed an increase in BOD) concentration of oxygen drops down; as oxygen is a vital element for the respiration of the living organisms, the organisms start to die off. The other reason for the massive death of the organisms, including fishes, is an increase in ammonia concentration. Toxic elements such as heavy metals that are present in industrial wastewater are accumulated in organisms and they cause negative effect especially on valuable predator species which are on the top of a food chain in ecosystem and get highest amount of toxicants.

Fishery is the most valuable and investigated biological resource in the river ecosystem and the impact on diversity is analysed by an example of fish populations. Some researchers from

Lithuanian Institute of Ecology have investigated diversity of fish fry species in the Nemunas. These studies are used to analyse the ecological impact of Kaunas wastewater.

The abundance of five fish fry species in the Nemunas just downstream Kaunas and about 20km downstream Kaunas was compared using long-term data by V. Ziliukas. The relative abundance (number of fish per $100m^2$) of vimba, bream and pike was lowest in the point just downstream the city at the left bank (the main wastewater outlet is on that side) and was increasing going farther downstream from the city. The relative abundance of roach was lowest in the point just downstream the city at the right bank. Only the relative abundance of perch was lower 20km downstream Kaunas than directly after the city. (*Ziliukas V., 1998*)

Biological diversity is considered to be big when many species are present in the ecosystem and the number of organisms per species is similar. The more contaminated river reach is, the smaller number of fish species is present and the higher amount of fish of present species is found. In the polluted areas a few low-commercial value species are abundant and other species are found in a very small number if found at all. The percent of fish population in the total number of all fishes is defined as specific gravity of the population. According to the study performed by V. Ziliukas, out of five compared fish species, roach had the highest specific gravity of population in the Nemunas downstream Kaunas and it had the lowest commercial value (other species were perch, vimba, bream and pike) (*Ziliukas V., 1998*). Another investigation of fish diversity in the Lower Nemunas was performed in 1989. The total amount of 17 fish species was registered. In the Nemunas in the most polluted western part of Kaunas only 7 species were found and one low-value species stickleback dominated totally (this species made up 96.7% of all catch!). A few kilometres downstream the city at the left bank 8 species were found, stickleback and roach were dominating. 20km downstream Kaunas 11 species were found already. Going downstream the river to the delta, a number of fish species decreased again after big industrial plants which were infamous for the discharges of highly contaminated wastewater in that time. (*LASIE, 1989*)

The abundance of every species compared to a total amount of fish is expressed as index of equivalence. Low index of equivalence refers to the situation with a few species when one or two of them are clearly dominating. The lowest index of equivalence in the Lower Nemunas is observed within the limits of Kaunas city. (*LASIE, 1989*)

Fish diversity was compared in the Lower Nemunas and in the Neris. Indices of biodiversity and equivalence were calculated in the Neris river and in the Nemunas after the confluence with the Neris. Both indices showed higher biodiversity in the Neris than in the Nemunas. (*Ziliukas V., 1986*)

In summary, fish diversity is extremely low in the Nemunas downstream Kaunas and urban wastewater plays a significant role here.

Wastewater management benefits for ecosystem

Kaunas pollution load has decreased in the last decade due to better water management and economic recession, but significant improvements in the state of the ecosystem were not registered. It was shown earlier that water quality in the river fluctuated during the last years and bigger positive changes in water quality will arise only after opening the wastewater treatment plant. Change in chemical water quality is a primary effect of reduced pollution load, increase in biological diversity and improvement of other ecological parameters are secondary effects (or primary impact) which need more time to be registered. So the ecological diversity is expected to become higher only some years after opening of the plant. The time period may be even longer for fish species, because habitat for fish which includes fish food material such as populations of weeds and micro-fauna has to recover before the fish species come back.

The regular monitoring of higher organisms should be developed in order make it possible to evaluate the benefits of the water management and suggest even better solutions for the future. The monitoring system for fish in the Nemunas downstream Kaunas and in the Neris is absent. The assessment of fish diversity and other ecological studies are rare and unsystematic. In 1999 a comprehensive study of the Lower Nemunas ecosystem is planned which will be a continuation of the study performed in 1989. 10 years period is not adequate for the natural resources overcoming big changes due to new management practices. The more often regular assessment of the ecosystem has to be found.

However, some changes in the aquatic ecosystem due to the lower wastewater pollution can be already predicted. The wastewater treatment will reduce the peaks of discharges of hazardous substances which are detrimental for the living organisms. 10% proposed reduction in concentration of oxygen consuming substances will reduce the extreme minimum in dissolved oxygen concentration which causes die out of some organisms. An example of changes in ammonia concentration is taken to show changes in fish diversity. According to V. Vinceviciene's model, ammonia concentration reaches its maximum downstream Kaunas city and it reduces later due to self-purification. With working Kaunas Wastewater Treatment Plant maximum concentration of ammonia at the point downstream Kaunas will be at the level that is now 20km downstream Kaunas (*Vinceviciene V., 1996*). Considering the negative effect of ammonia on fish population and that higher fish biodiversity was registered 20km downstream Kaunas, the biodiversity just downstream Kaunas is predicted to reach the level that is now 20km downstream the city.

Reduced pollution load from Kaunas will improve water quality in the river all the way down to the delta. This will slightly ameliorate ecosystem of the whole river. It means that life conditions for the animals in the river will improve as most of the species migrate and do not stay in one place all the life-span. Wastewater management in Kaunas will contribute to ecological well-being of the river ecosystem.

The treated wastewater will be discharged downstream the city, 7km below the main wastewater outlet at present and 10km downstream the Neris. It means that the part of the Nemunas river in the western part of the city which gets the heaviest impact now, will not receive wastewater pollution load and will have a possibility to recover. The ecosystem is in the worst condition in this segment of the river and long time will be needed for the ecosystem to improve. Wastewater will be discharged straight after the confluence with the Nevezis. This will increase water flow used for dilution of the wastewater about 10% and it will improve water quality slightly as water in the Nevezis is cleaner than in the Nemunas before this confluence.

The changes in the river ecosystem downstream Kaunas will depend on changes in water quality in the Neris river, i.e. on the decisions made to reduce the negative impact on the Neris from agricultural sources and from Vilnius city.

Impacts and benefits for human welfare

The social and natural systems are open systems and an impairment in one system causes a negative effect on the other system. Surface water pollution deteriorates natural environment and natural resources of water bodies, such as water and fisheries. Deterioration of resources causes negative impact on population, especially local population that uses the resources for their needs.

Pollution in the river causes effect on the local population through potable water and the river water in the territories of beaches. Waterborne diseases caused by the river pollution have not been registered. But the health risk exists because of water contamination and it should be diminished.

Quality of potable water

The pollution in the Nemunas river may cause adverse effect on the potable water quality. Interrelation between water flow in the natural system and water use in the urban system is demonstrated in figure 4.1. The river water is the main source for the raw water. Urban population use groundwater, that is the raw water infiltrated through soil, gravel naturally. Then groundwater is consumed in household and industry. Industry uses the river water for technical processes too. The used water becomes wastewater that is discharged back into the surface water body, in Kaunas city case, the Nemunas river.

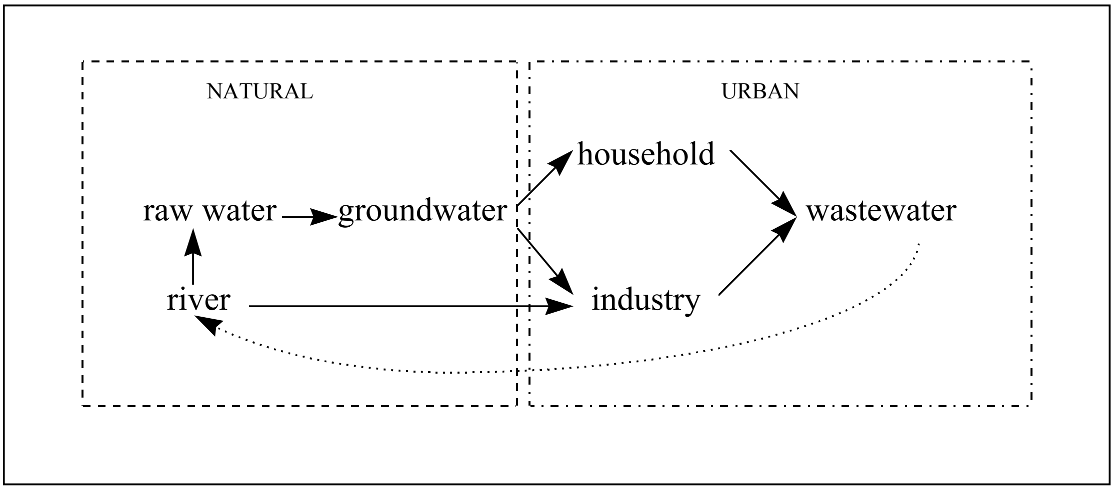


Figure 4.1. Water flow through natural and urban systems.

Kaunas city satisfies potable water needs with groundwater. The river water is not used for drinking nor any other household needs. There are four groundwater well fields in Kaunas today, that supply Kaunas city with 197 000 m^3 potable water per day. The water is drawn from the gravel deposits along rivers the Nemunas and the Neris. The water bearing stratum has a thickness of 20 to 40 meters. Nearly all the water naturally infiltrates from the rivers. Two groundwater well fields are located along the Neris river, the other two fields are located along the Nemunas river. The biggest well field among them is the one located upstream the city along Kaunas reservoir. The groundwater well fields are shown in figure 1.1.

The quality of the potable water does not fulfil all the requirements and concentration of some elements exceeds the drinking water standards. The groundwater coming to potable water distribution system has high iron and manganese concentration. Iron concentration is between 0.1 and 0.28mg/l in three well fields and between 0.6 and 0.9mg/l in the biggest well field while the local standard for iron is 0.3mg/l. The standard adopted in the European Community is 0.05mg/l. High iron concentration leads to precipitation of iron hydroxide, high colour and bad taste. The raw water has high concentration of iron. Iron concentration increases through natural infiltration and artificial recharge through sand layers.

Manganese concentration in the groundwater is between 0.05 and 0.2mg/l in three well fields and much higher in the biggest well field, 0.4 - 0.8mg/l. The Lithuanian standard is 0.1mg/l, the norm in the European Community is 0.02mg/l. High manganese concentration leads to the growth of manganese bacteria in the pipelines which precipitate black manganese oxide. The latter gives ‘black water’ that is unsatisfactory from an aesthetic point of view. Manganese concentration is low in the rivers, but increases during the passage through the soil layers.

The alkalinity and hardness of drinking water are fairly high, but it does not exceed the standards. When the water is heated, calcium carbonate precipitates as a hard layer and may lead to clogging of boilers and other equipment used in industry or household. Concentration of fluoride fulfils the requirements for water. Pollution of potable water with hazardous substances such as heavy metals and bacteriological pollution is not registered.

Pathogenic bacteria are not observed in the potable water. Total number of coliform bacteria reaches 10^4 bacteria per litre in the rivers along infiltration zones. The raw water is treated by chlorination only. Even if no increase in bacteriological pollution of the potable water is observed, the health risk remains while concentration of bacteria is high in the rivers. (*K-Konsult, 1994*)

In summary, negative effect of anthropogenic pollution in the river on the quality of potable water is not observed in Kaunas.

A new groundwater well field is prepared for exploitation. Groundwater in that field contains less iron and all parameters fulfil drinking water standards. But the new field is located along the Nemunas river downstream the centre of Kaunas. Water quality in the river is much more deteriorated in that part of the city than upstream. The bacteriological pollution in the river downstream the wastewater outlets is very high. Coli index reaches the value of 10^7 bacteria per litre. Risk for deterioration of potable water quality if pollution in the river was not reduced may increase. Kaunas wastewater treatment plant will reduce the possible negative impact on potable water quality, because it will treat the wastewater and, especially, because wastewater from the city will be discharged on the other place which is downstream the infiltration zones for the new well field.

Due to Kaunas Water and Environment Project wastewater that was discharged through several outlets will be directed to the treatment plant and the effluence of polluted wastewater within the city area will be eliminated. In this way the risk for deterioration of potable water quality in all groundwater well fields will be reduced.

Recreation

Recreation is the social activity depending on water quality in the river. Bacteriological pollution, water turbidity, colour and eutrophication are the negative aspects and effects of improper water management disturbing recreational activity, especially bathing in the surface water bodies. High water turbidity, bad colour and algae blooming (eutrophication) frighten visitors, because the water in the beaches becomes unattractive from an aesthetic point of view. The bacteriological pollution bears direct health risk. The impact on recreation caused by the river pollution is analysed with a help of bacteriological monitoring.

In the Kaunas city the beaches are located along the Nemunas river and at the Lampedziai reservoir. The two beaches along the river are located in the territory of the city (beaches B1 and B2 in figure 1.1). They were the most popular beaches in Kaunas. The beaches are closed now, because of the big bacteriological pollution. The beach at the Lampedziai reservoir is explored instead, because its water quality is better and the possibilities to reach the reservoir by public transport are very good. The Lampedziai reservoir is not big enough for Kaunas population and people are willing to use the beaches along the river if water quality improves there.

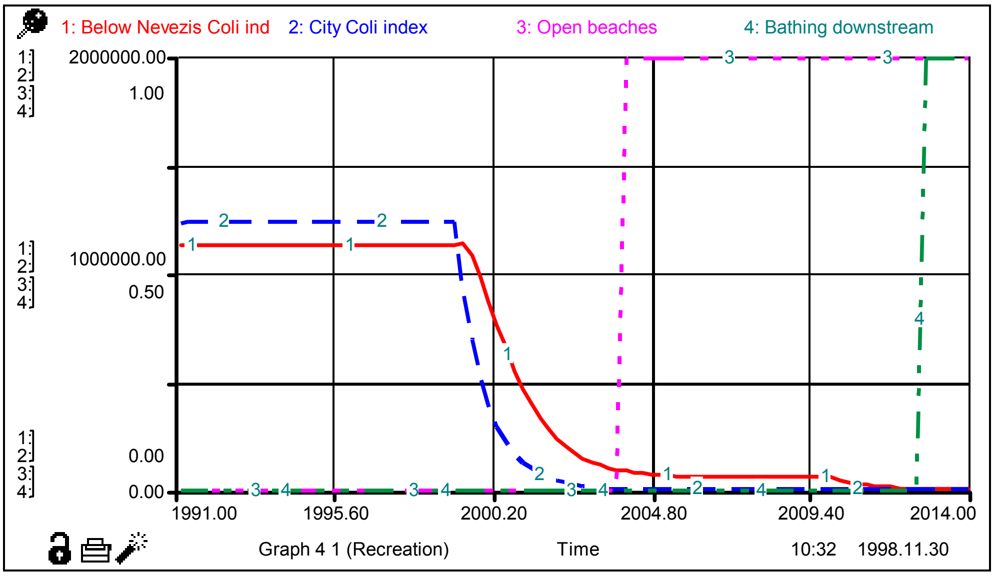
The existence of fecal coliform bacteria indicates that water body is contaminated with coliform bacteria recently and there is a high probability of pathogenic organisms. Enteropathogenic bacteria can course severe diseases. One of the best indicators to evaluate if surface water body can be used for bathing is coliform bacteria. Highest allowable concentration for bathing is $5*10^3$ coliform bacteria per 1litre in Lithuania.

Wastewater management is expected to improve bacteriological quality of the Nemunas river significantly, especially in the territory of Kaunas. In 1999 municipal wastewater will be directed to the treatment plant and only a few surface urban stormwater outlets will be left in the territory of the city. The treated wastewater will be discharged downstream the city and downstream the beaches. Water in the two beaches located along the river reach (B1 and B2) will not be affected by polluted wastewater. Water quality is expected to become close to the quality of the Kaunas reservoir. Bacteriological pollution will not exceed the limits, the health risk will be eliminated and the beaches will be opened for bathing and other recreational activities.

Model B: Impact of the wastewater management on recreation

The impact of the wastewater management on recreation was analysed by an example of the effect of bacteriological pollution of the wastewater on possibilities to bathe in the Nemunas river. The surface water quality data from Public Health Centre from summer 1997 were used for the Stella model. The results are presented in graph 4.1. The model is given in the appendix.

'City Coli index' determines a maximum number of coliform bacteria per litre in the Nemunas river within Kaunas city. 'Below Nevezis Coli index' determines a number of coliform bacteria per litre in the Nemunas river below the inflow of the Nevezis, i.e. downstream of the new wastewater outlet which will discharge the treated wastewater of Kaunas. The results of the model shows that when the wastewater from all the sewage outlets will be directed towards the treatment plant and all the outlets within Kaunas will be closed, bacteriological water quality in the beaches within Kaunas will not exceed the sanitary norms and the beaches will be opened. 95% reduction in bacteriological pollution during the mechanical wastewater treatment will not be enough to reach sanitary norms in the Nemunas below the inflow of the Nevezis. The model shows that Bathing downstream reaches a value of 1 after 2010, it means that bathing downstream of the city will be allowed only after the biological treatment which could reduce 99.9% of coliform bacteria (the predicted treatment efficiency is taken from *K-Konsult, 1994*).



Graph 4.1. Impact of the bacteriological wastewater pollution on recreational bathing.

The model shows that Kaunas Wastewater Treatment Plant will reduce the negative impact on recreational activities caused by the bacteriological pollution of urban wastewater. Social impact on population living along the Nemunas downstream Kaunas will be reduced to such an extent that water in the river will be suitable for bathing only after opening of the biological treatment.

The river is not only a part of natural environment, but also a part of urban and social environment. The inhabitants of Kaunas are proud living close to the confluence of the two biggest Lithuanian rivers and they are willing to see the rivers cleaner. Cleanness of the rivers affects self-confidence of people and increases general well-being of the society. The water management measures that bring positive impact on the river ecosystem and take into consideration reduction of social impact of water pollution are beneficial for the human environment in a broad sense.

V. GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The main objectives adopted in Kaunas wastewater management are oriented towards improvement in chemical water quality. Orientation towards reduction of impact on the whole aquatic ecosystem and human welfare is lacking. For this purpose broader scope of the management should be developed substantiating actions by the concrete positive impact on the environment and population.
2. The analyses showed that the positive effect on water quality of the river due to the economic recession and the incentives to reduce wastewater production is higher than the positive effect due to Kaunas Wastewater Treatment Plant. When industrial activity starts to recover and the pollution of wastewater increases, the treatment plant is needed to increase positive effect of the management system on the river further.
3. Assessment of ecological state of the river ecosystem is very weak. Analysis of the resources and regular monitoring of fish and other organisms would help to identify impact of the urban wastewater on the river ecosystem. Comprehensive ecological studies should be encouraged.
4. Environmental and social impact caused by the untreated wastewater is not known. Environmental Impact Assessment has not been performed for Kaunas Wastewater Treatment Plant. Improvements in the natural and social environment that will be caused by the treatment of the wastewater were not investigated earlier. Regulations on EIA are developed now and comprehensive EIA programme should be prepared for further water management actions, on the first place for the biological wastewater treatment.
5. Kaunas wastewater increases eutrophication and reduces fish diversity in the Nemunas downstream Kaunas. The wastewater treatment plant will improve water quality in the river up to 15% and the ecological state of the ecosystem is expected to improve slightly.
6. Pollution in the river, especially discharge of the wastewater containing coliform bacteria, imposes health risk on the river water and the beaches along the river can not be used for bathing and other recreational activities. Due to the direction of the wastewater to the treatment plant, bacteriologically polluted wastewater will not be discharged within Kaunas territory and it will become possible to use the beaches along the river again. Bathing in the Nemunas downstream the city will be possible only after opening of the biological treatment. Kaunas wastewater causes no impact on the quality of potable water.
7. Kaunas wastewater is not the only pollution source for the Nemunas river in Kaunas city zone. To achieve significant improvement in the Nemunas river ecosystem, water management measures in Kaunas should be coordinated and planned together with other municipalities along the Nemunas and, especially, along the Neris river.

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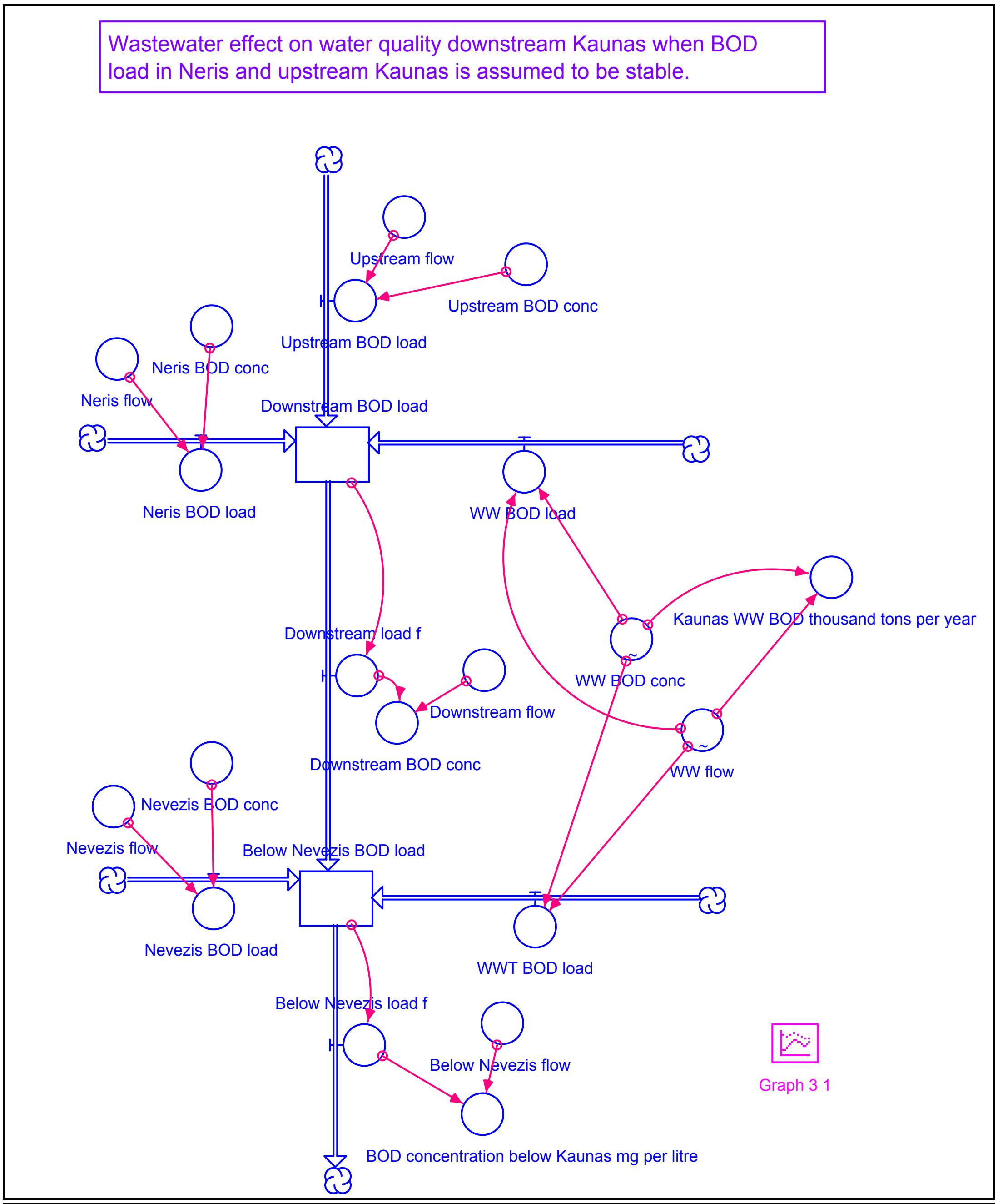
Note: * - Lithuanian text, English abstract.

Appendix

<u>Model A: Effect of the wastewater management on water quality in the river</u>



Model A formulae:

Below_Nevezis_BOD_load(t) = Below_Nevezis_BOD_load(t - dt) + (Downstream_load_f + Nevezis_BOD_load + WWT_BOD_load - Below_Nevezis_load_f) * dt

INIT Below_Nevezis_BOD_load = 63 {thousand tons BOD7/year}

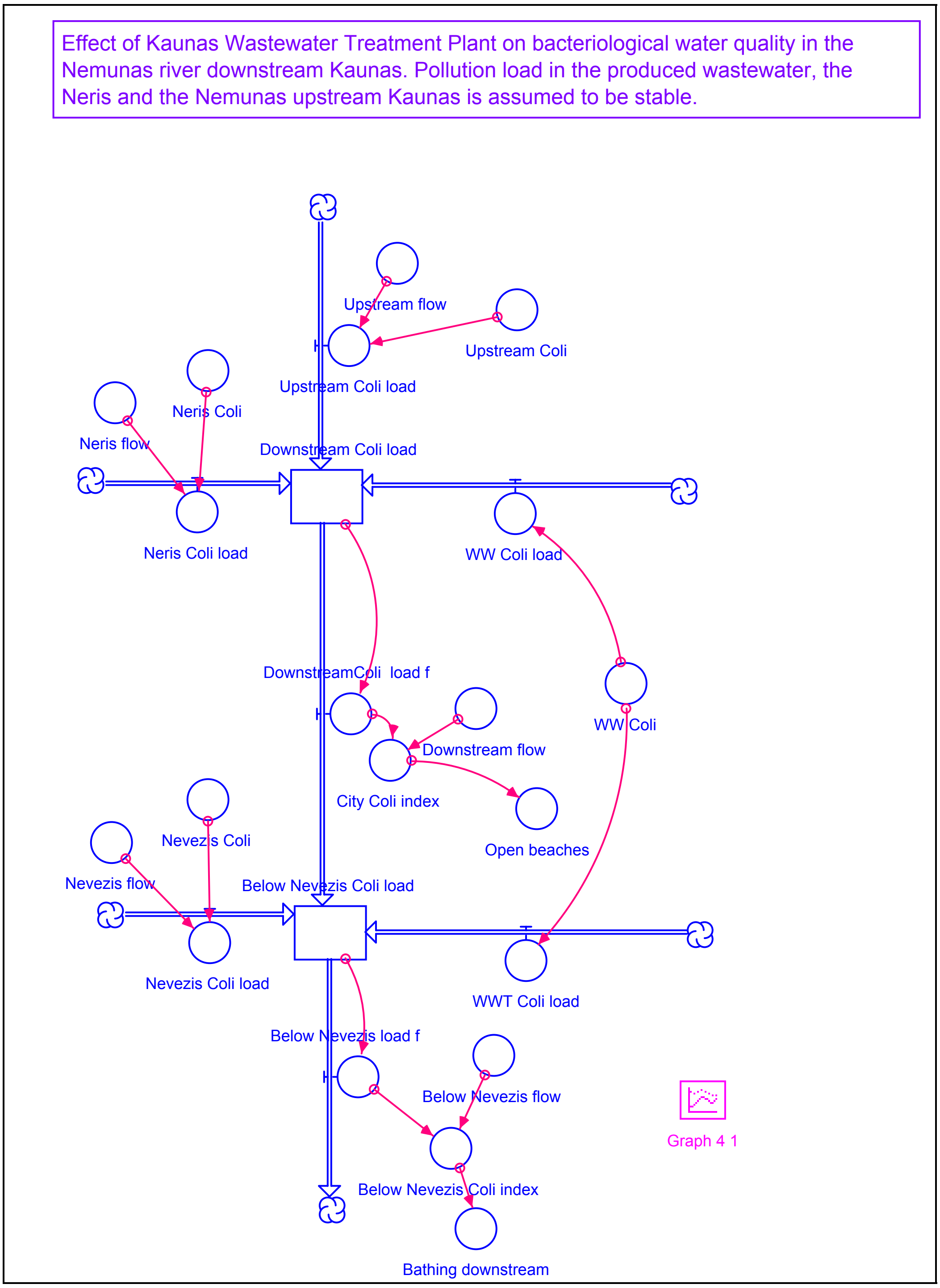
INFLOWS:
Downstream_load_f = Downstream_BOD_load {thousand tons BOD7/year}
Nevezis_BOD_load = Nevezis_BOD_conc*Nevezis_flow*31536000/10^9 {thousand tons BOD7/year}
WWT_BOD_load = IF(TIME>=1999)THEN(WW_BOD_conc*WW_flow*31536000/(10^9))ELSE(0) {thousand tons BOD7/year}
OUTFLOWS:
Below_Nevezis_load_f = Below_Nevezis_BOD_load {thousand tons BOD7/year}

Downstream_BOD_load(t) = Downstream_BOD_load(t - dt) + (Upstream_BOD_load + Neris_BOD_load + WW_BOD_load - Downstream_load_f) * dt
INIT Downstream_BOD_load = 60 {thousand tons BOD7/year}

INFLOWS:
Upstream_BOD_load = Upstream_BOD_conc*Upstream_flow*31536000/10^9 {thousand tons BOD7/year}
Neris_BOD_load = Neris_BOD_conc*Neris_flow*31536000/10^9 {thousand tons BOD7/year}
WW_BOD_load = IF(TIME<1999)THEN(WW_BOD_conc*WW_flow*31536000/(10^9))ELSE(0) {thousand tons BOD7/year}
OUTFLOWS:
Downstream_load_f = Downstream_BOD_load {thousand tons BOD7/year}

Below_Nevezis_flow = 415 {m3/s}
BOD_concentration_below_Kaunas_mg_per_litre = Below_Nevezis_load_f*10^9/(31536000*Below_Nevezis_flow) {mg O2/litre}
Downstream_BOD_conc = Downstream_load_f*10^9/(31536000*Downstream_flow) {mgO2/litre}
Downstream_flow = 374 {m3/s}
Kaunas_WW_BOD_thousand_tons_per_year = WW_BOD_conc*WW_flow*31536000/(10^9) {thousand tons BOD7/year}
Neris_BOD_conc = 5.55 {mgO2/l}
Neris_flow = 152 {m3/s}
Nevezis_BOD_conc = 2.18 {mgO2/l}
Nevezis_flow = 33.3 {m3/s}
Upstream_BOD_conc = 2.085 {mgO2/l}
Upstream_flow = 240 {m3/s}
WW_BOD_conc = GRAPH(time)
(1991, 222), (1992, 183), (1993, 170), (1994, 167), (1995, 149), (1996, 140), (1997, 180), (1998, 192), (1999, 80.0), (2000, 80.0), (2001, 80.0), (2002, 80.0), (2003, 80.0), (2004, 80.0), (2005, 80.0), (2006, 80.0), (2007, 80.0), (2008, 80.0), (2009, 80.0), (2010, 17.0), (2011, 17.0), (2012, 17.0), (2013, 17.0), (2014, 17.0)
WW_flow = GRAPH(time)
(1991, 2.19), (1992, 1.62), (1993, 1.78), (1994, 1.54), (1995, 1.37), (1996, 1.04), (1997, 0.76), (1998, 0.76), (1999, 0.8), (2000, 0.9), (2001, 1.00), (2002, 1.10), (2003, 1.20), (2004, 1.30), (2005, 1.37), (2006, 1.37), (2007, 1.37), (2008, 1.37), (2009, 1.37), (2010, 1.37), (2011, 1.37), (2012, 1.37), (2013, 1.37), (2014, 1.37)

Model B: Impact of the wastewater management on recreation



Model B: formulae

Below_Nevezis_Coli_load(t) = Below_Nevezis_Coli_load(t - dt) + (DownstreamColi__load_f + Nevezis_Coli_load + WWT_Coli_load - Below_Nevezis_load_f) * dt

INIT Below_Nevezis_Coli_load = 1.46*10^19 {bact/year}

INFLOWS:
DownstreamColi__load_f = Downstream_Coli_load {bact/year}
Nevezis_Coli_load = Nevezis_Coli*1000*Nevezis_flow*31536000 {bact/year}
WWT_Coli_load = IF(TIME>=2010)THEN(WW_Coli*0.001)
ELSE(IF(TIME>=1999)THEN(WW_Coli*0.05)ELSE(0)) {bact/year}
OUTFLOWS:
Below_Nevezis_load_f = Below_Nevezis_Coli_load {bact/year}

Downstream_Coli_load(t) = Downstream_Coli_load(t - dt) + (Upstream_Coli_load + Neris_Coli_load + WW_Coli_load - DownstreamColi__load_f) * dt

INIT Downstream_Coli_load = 1.46*10^19 {bact/year}

INFLOWS:
Upstream_Coli_load = Upstream_Coli*1000*Upstream_flow*31536000 {bact/year}
Neris_Coli_load = Neris_Coli*1000*Neris_flow*31536000 {bact/year}
WW_Coli_load = IF(TIME<1999)THEN(WW_Coli)ELSE(0) {bact/year}
OUTFLOWS:
DownstreamColi__load_f = Downstream_Coli_load {bact/year}

Bathing_downstream = IF(Below_Nevezis_Coli_index<=5000)THEN(1)ELSE(0) {open beaches(1) or not(0)}

Below_Nevezis_Coli_index = Below_Nevezis_load_f/(1000*31536000*Below_Nevezis_flow) {bact/l}

Below_Nevezis_flow = 410 {m3/s}

City_Coli_index = DownstreamColi__load_f/(1000*31536000*Downstream_flow) {bact/l}

Downstream_flow = 374 {m3/s}
Neris_Coli = 750 {bact/l}
Neris_flow = 152 {m3/s}
Nevezis_Coli = 750 {bact/l}
Nevezis_flow = 33 {m3/s}

Open_beaches = IF(City_Coli_index<=5000)THEN(1)ELSE(0) {open beaches(1) or not(0)}

Upstream_Coli = 750 {bact/l}
Upstream_flow = 240 {m3/s}
WW_Coli = 1.46*10^19 {bact/year}