THESIS ON CIVIL ENGINEERING F28

Water Resources, Sustainable Use and Integrated Management in Estonia

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TUT PRESS

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Dissertation was accepted for the defence of the degree of Doctor of Philosophy in Civil and Environmental Engineering on May 17, 2010

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Defence of the thesis: June 21, 2010

Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

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ISSN 1406-4766
ISBN 978-9949-23-005-1

EHITUS F28

Veevarud, nende terviklik haldamine ja säästlik kasutamine Eestis

KARIN PACHEL

TTÜ KIRJASTUS

CONTENTS

1 INTRODUCTION

1.1 Background

The United Nations Commitee on Economic, Social and Cultural Rights adopted General Comment No. 15 (GC15) in 2002 where water is recognized not only as a limited, vulnerable resource and a public good but also as a basic human right to have access to clean as well as safe, accessible, sufficient water and sanitation at an affordable price (General Comment No. 15, 2002). By GC15, water should be treated as a social and cultural good, accessible to everyone and not primarily as an economic good. Accessibility includes also the right to have full and equal access to information concerning water, water services and the environment, held by public authorities or third parties.

The quantity of water used by households has an important influence on human health. An adult requires approximately two litres of drinking water per day dependant on climate, activity level and diet (World Health Organisation, 2008). To meet direct human consumptive needs 7.5 litres per capita per day is calculated as the basic minimum water requirement for hydration and incorporation into food for most people under most conditions (Howard & Bartram, 2003; World Health Organisation, 2008). Additional water is needed for laundry, personal and domestic hygiene. It is known that only about 1% of all water found on Earth is easily accessible for human use. Water with suitable quality for abstraction, especiallly drinking water is limited by geography, demography and affordability.

According to World Water Development Report 3 the world's water withdrawals have tripled over the last 50 years (UN, WWDR3, 2009). Total global freshwater use is estimated at about 4,000 km^3 a year or around 600 m^3 per year per capita. Globally, humans appropriate more than 50% of all renewable and accessible freshwater, while billions still lack the most basic water services (Palaniappan & Gleick, 2009). Competition for water exists at all levels and is forecast to increase with demands for water in almost all countries. Further growth of the world's population will increase water demand as well as water pollution in the future. In 2030, 47% of the world's population will be living in areas of high water stress (UN, WWDR3, 2009). Globally eutrophication of water bodies is the main water quality problem, which substantially impairs beneficial uses of water. The increased intensity of water use, discharge of unsufficiently treated domestic and industrial wastewaters, excessive application of fertilisers and pesticides in agriculture have led to an increasing pollution of water bodies.

In Europe the "good status" of all water bodies and groundwater has to be achieved by 2015 and therefore, as a minimum, sufficient treatment level of wastewater required by the Urban Waste Water Treatment Directive (UWWTD) should be achieved. All settlements with a population of 2,000 or more should have sewage collection systems and a minimum of secondary treatment. Additionally the Member States of HELCOM adopted an action plan to considerably reduce the anthropogenic nutrient load to the Baltic Sea and restore a good ecological status by 2021.

The levels of wastewater treatment in Europe have significantly improved since the 1970s, leading to markedly lowered discharge of organic matter and nutrients to recipient water bodies (UNEP/DEWA-Europe, 2004). The average nitrate concentration in European rivers has decreased by approximately 10% since 1998, and in lakes by 15%. Phosphorus concentrations in European rivers and lakes have generally decreased during the last 14 years (EEA, CSI 020, 2009). Nitrate concentrations in Europe's groundwaters that increased in the first half of the 1990s have afterwards remained relatively constant. Nevertheless, it is difficult to draw direct relationships between these marked changes in water quality and e.g. effeciency of measures to reduce agricultural inputs of nitrates, to improve wastewater treatment and other measures. We still have knowledge gaps with regard to the status of our water resources and water use and restricted information and data for decision making. Accurate and reliable, detailed data about water quality and resources help decision makers to assess water risks and the status of water bodies more authentically, and are essential for the development, implementation, monitoring and evaluation of EU policies (European Communities, 2009).

The quality of information systems varies between countries, but there are common problems with the assessment of the magnitude of the demand and the withdrawal of water, that are often estimated rather than measured or collected from censuses (UN, WWDR3, WCW, 2009). The national data sets are often owned and managed by governments instead of being available in the public domain. However, data alone cannot say much. The targeted as well as future prospects considering the management and use of the generated data converted into information and knowledge make it possible to rationally address priority issues and compile effective management plans, resulting in the improvement and sustainable use of water bodies.

The European Sustainable Development Strategy (ESDS) (COM, 2009) underlines the necessity of improving integrated water resources management (IWRM) and avoiding overexploitation. The main principle of IWRM is to promote sustainable and balanced use of natural resources, to ensure their co-ordinated development and management, to integrate water resources management with other fields by maximising economic and social welfare without compromising the sustainability of vital environmental systems (GWP, 2000). Water development and management should involve stakeholders at all levels including water users, planners, scientists, policymakers, local municipalities and the public.

The nature of water problems requires the integration of technical, economic, environmental, social and legal aspects into a coherent framework. River basin has been acknowledged to be an appropriate unit for integrated water resources management both by the WFD and the ESDS. In river basins internet based decision support systems, including information management systems (IMS), with the GIS component and modelling can be used by policy makers and managers for their decision making on water resources. These tools also enable the testing of "what if" scenarios.

1.2 List of original publications

Paper I: Pachel, K., 2002. Estonian national report on nutrient loads. In: Evaluation of the implementation of the 1988 Ministerial Declaration regarding nutrient load reductions in the Baltic Sea catchment area. Finnish Environment 524, International cooperation, Finnish Environment Institute, 90–102.

Paper II: Stålnacke, P., Sults, Ü., Vassiljev, A., Skakalsky, B., Botina, A., Roll, G., **Pachel, K**., Maltsman, T., 2002. An assessment of riverine loads of nutrients to the Lake Peipsi. Archiv für Hydrobiologie. Supplementband. Large rivers 141, 437–457.

Paper III: **Pachel, K**., 2005. On receiving water and self monitoring in Estonia and Viru-Peipsi project area with regard to drafting water resource management programs. In: Lääne, A., Heinonen, P. (eds), Sampling: Presentations of three training seminars about Quality Assurance (QA), Biological methods of Water Framework Directive and Waste water sampling techniques. Suomen Ympäristökeskuksen moniste 328, Finnish Environment Institute SYKE, 19–35.

Paper IV: Ennet, P., **Pachel, K**., Viies, V., Jürimägi, L., Elken, R., 2008. Estimating water quality in river basins using linked models and database. Estonian Journal of Ecology, 57(2), 83–99.

Paper V: Iital, A., **Pachel, K**., Deelstra, J., 2008. Monitoring of diffuse pollution from agriculture to support implementation of the WFD and the Nitrate Directive in Estonia. Environmental Science and Policy, 11(2), 185–193.

Paper VI: Iital, A., **Pachel, K**., Loigu, E., Pihlak, M., Leisk, Ü., 2010. Recent trends in nutrient concentrations in Estonian rivers as a response to large-scale changes in land-use intensity and life-styles. Journal of Environmental Monitoring, 2010, 12, 178–188.

1.3 Author´s contribution

Paper	Original idea	Study design and methods	Data collection and handling	Contribution to result interpretation and manuscript preparation	Responsible for result interpretation and manuscript preparation
I	x	x	x	x	x
II		x	x	x	x
III	x	x	x	x	x
IV	x	x	x	x	x
V		x	x	x	x
VI			x	x	x

1.4 Objectives

The main objectives of the doctoral thesis were:

1. to assess the availability of water resources, water use and current status in Estonia
2. to analyse nutrient trends in rivers and nutrient load to the recipient water bodies including the Baltic Sea,
3. to develop scenarios to decrease nutrients point source pollution load
4. to develop decision supporting tools for integrated river basin management
5. to analyse the existing water resources knowledge base data management and to make proposals on development

Acknowledgements

I would like to express my sincere thanks to my supervisors Professor Enn Loigu and Associated Professor Arvo Iital for their great support and confidence in me.

I would like to thank researchers at Tallinn University of Technology, especially Professor Emeritus Heino Mölder, and colleagues at the Estonian Environment Information Centre of the Ministry of the Environment of Estonia, with whom I have had fruitful and interesting discussions.

Thanks to my parents and to my children for encouraging and supporting me during this long study period and in memoriam to Hillar Pachel.

2 WATER RESOURCES

2.1 Legal basis for water management in Estonia

Water management planning in Estonia is guided by the EU water framework directive (WFD) (Directive, 2000) and other relevant directives regulating the use and protection of water environment. According to the WFD water management is based on river basins. The principle of cost recovery and the polluter pays principle should be taken account. Use of emission limit values and environmental quality standards should be ensured. Programs for monitoring of water bodies in order to have a comprehensive overview of water status should be established. Active involvement of the public in the development of river basin management plans and in decision processes should be encouraged.

The most general goals and objectives of sustainable water management in Estonia are formulated in the National Environmental Strategy up to the year 2030 and in the Estonian National Environmental Action Plan for 2007-2013. The Water Act is the main legal instrument for water policy that regulates water resources management in Estonia. Following the IWRM principles, the Water Act states that the use and protection of water should be organized by the government. Local governments are responsible for water supply and sewerage, and for establishing temporary restrictions concerning the use of drinking water within their administrative jurisdiction. The purpose of the Water Act is to promote sustainable water use by integrating water resources management with other fields in order to ensure an ecological balance in water bodies and healthy and safe drinking and bathing water (RT I 2010, 8, 37).

Measures for water protection and use shall be defined in a river basin or sub-river basin management plan. Public water supply and sewerage development plans, comprehensive plans and detailed plans of the local government should be consistent with river or sub-river basin management plans. The Act on Sustainable Development of Estonia aims at a more sustainable use of the natural environment and natural resources to ensure that the environment meets human needs as well as provides the resources necessary for economic development without causing significant damage to the environment and without depleting biological diversity.

According to the Water Act, a user must hold a permit with a specified term for special water use, which is the use of water with technical equipment, constructions or substances which could affect the condition of a water body or aquifer. The permit establishes the rights and obligations for water users, and the monitoring and reporting responsibilities related to water use, enabling direct implementation of the national water policy. Before obtaining a permit an environmental impact assessment of the planned activity may be necessary. According to the

Environmental Impact Assessment and Environmental Management System Act an environmental impact assessment is conducted by a person who plans an activity and intends to perform it.

The revised Water Act will completely follow the basic principles of integrated water resource management and will include a provision that the conditions of the permit for the use of water should correspond to the environmental purposes of the Water Management Plan. The Environmental Charges Act provides the main principles for the determination of natural resource charges, the rates of pollution charge, the procedure for calculation and payment thereof, and specifies the purposes for using the proceeds paid into the state budget.

2.2 Indicators of water availability, abstraction, use and price

Environmental indicators, as prime assessors of the pressures on the environment, of the evolving state of the environment, and of the appropriateness of policy measures, have come to play a vital role in environmental reporting (Niemeijer & de Groot, 2008). Water management indicators play an important role in the development and reviewing of water policies and plans, setting of targets and estimating the effectiveness of monitoring programs, as well as showing how well the objectives are met. Indicators make information more transparent, support communication with the public and help to evaluate performance on the local and state level. The major water related indicators adopted in Estonia include water resources availability, abstraction and use, water exploitation index, wastewater treatment, resource and pollution charge and water supply and wastewater price.

2.2.1 Water resources availability

Estonian water resources are generally sufficient to satisfy human needs and ecosystem requirements, but they are unevenly distributed. Especially in North Estonia, where most of the country's industrial activities are located, surface water resources are quite limited. Mean annual precipitation amounts to 650–750 mm, evaporation is 470-480 mm and the rivers runnoff is 270-290 mm, which constitutes 35-40% of the precipitation level (Environmental Report 7, 1993). The total runoff of Estonian rivers in an average year is 11.7 cubic kilometers, being only 5.5 and 4.2 cubic kilometers in very dry (95% probability) and extremely dry (99% probability) years, respectively (Eipre, T., 1980).

The stream system is relatively dense; the network of rivers longer than 10 km is 0.23 km/km^2. Most rivers are short and there are only 10 rivers longer than 100 km and 15 rivers with catchment areas exceeding 1,000 km^2. Only 13 rivers have their mean annual average flow over 10 m^3. Upper parts of Estonian rivers are particularly poor in water and in low water periods the flow can be near zero. This situation causes problems in using rivers as recipients for wastewater discharge because dilution can be insufficient, thus highly efficient wastewater treatment is required.

The annual recharge of groundwater resources by infiltration of precipitation is on the average 70 mm/year (Eesti põhjavee kasutamine ja kaitse, 2004). Nevertheless, groundwater resources are quantitatively limited and water balance is a serious issue especially in the North-East Estonian oil shale basin and around Tallinn. Northern part of Estonia is characterised by widespread karst phenoma. Therefore, the natural quality of groundwater can easily be degraded because of human activity.

2.2.2 Water demand, abstraction and use

A minimum of 135 l/per capita/per day (including water distribution losses) is required for social and economic development that would permit the achievement of high human development (Chenoweth, 2007). The World Health Organisation has provided guidance on the quantity of domestic water required to promote good health (World Health Organisation, 2008). By the guidelines the volume of water used by households is primarily a function of the distance to the water supply, broadly equating to the level of service. Two out of four levels of services defined by the guidelines are more common in Estonia: 1. intermediate access if single tap is in house or yard, and 2. optimal access if water is piped into the home thorough multiple taps. For the intermediate access, around 50 litres per capita per day should be available as an average, thus public health risk from poor hygiene as well as intervention priority and actions are low (Howard & Bartram, 2003; World Health Organisation, 2008). Sufficient water is available to meet all domestic needs. For optimal access of water around 100-200 litres per capita per day should be available to secure that health risk, intervention priority and actions are very low (Howard & Bartram, 2003; World Health Organisation, 2008).

In Europe the average yearly per capita abstraction is about 500 cubic meters of water of which 44% is used for energy production, 24% for agriculture, 21% for the public water supply and 11% for industry (EEA, 2009). Water abstraction for public water supply in Eastern European countries (incl. Estonia) decreased by one third between the 1990s and the early 2000s. The decreasing tendency was characteristic also to Western Europe while an increasing trend prevails in Southern Europe. National average per capita of public water supply ranges between 50 and 150 m^3 annually (EEA, 2009).

As an average 90 litres of water per capita per day (l/c/d) were used for human consumption in Estonia. This level is about 50% compared to 188 l/c/d in 1992 (EER, 2010). The decrease was caused by a decline in manufacturing, implemented policy measures and increased water price that promoted a more sustainable use of water in the domestic sector and industries and investments into the renovation of pipes between 1992 and 2008 (Figure 2.1).

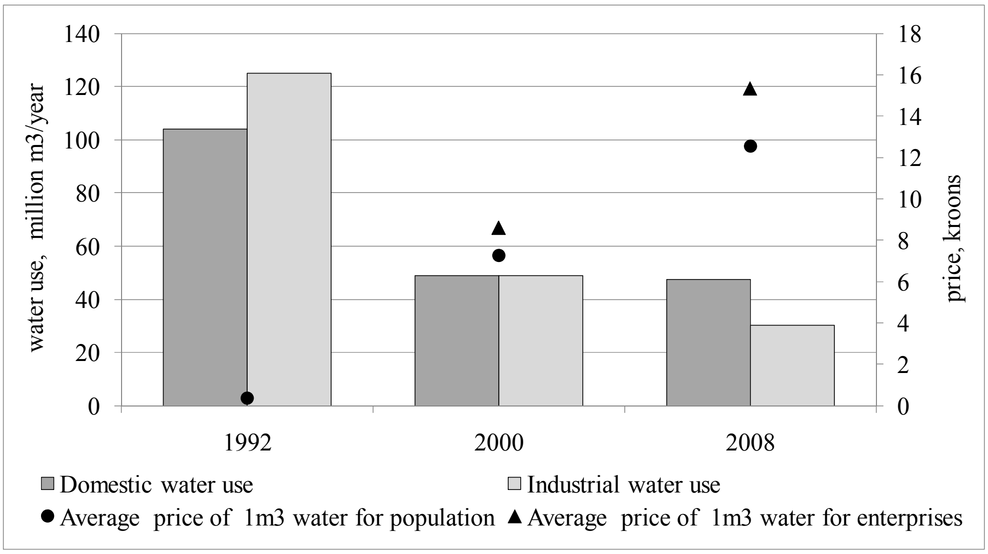


Figure 2.1 Water use and average water supply price in Estonia

The changes in water use patterns led to the situation where domestic water consumption norms enacted by Regulation of Ministry of Environment nr 24, in 1993 appeared to be excessively high, i.e. up to 300 l/c/d. Therefore the norms enacted by local municipalities or European standards should be used until new consumption norms are established. According to the national water use database per capita domestic water use varies a lot in Estonian settlements (Table 2.1).

Table 2.1 Water use indicators of some settlements in 2009

County	Settlement	Inhabitants served by water supply	Annual domestic water use, th. cubic meters	Annual domestic water use, l/c/d
Harju	Kose	1,430	49.2	94
	Palvere	100	1.9	52
	Tallinn	402,636	12,881.6*	
Lääne	Haapsalu	11,300	448.8	109
Tartu	Alatskivi	320	18	154
	Vaabina	45	2.4	148
Viljandi	Abja-Paluoja	1,120	35	86
Ida-Viru	Kukruse	700	84.6	331
Pärnu	Pärnu	39,200	2,011.9	141

* water used in domestic and industry sector

In Estonia abstraction of water is metered rather correctly by water users and monthly information on water volumes used in domestic, industry and agriculture were in most cases well presented. Only AS Tallinna Vesi, the company serving about one third of the Estonian population, does not measure water use separately by activity areas and industries in its whole service area. Thus, the data on annual domestic water use for the whole country, lacking the data for the Tallinn area, are misleading. The study results of 37 apartment buildings in Mustamäe district, Tallinn, show that the average water use in 1999 was 129 l/c/d, varying between 106 and 156, dropped to 94 l/c/d in 2004, within a range of 78 and 115 l/c/d (TTÜ, 2005). This level is quite similar to the data submitted to the national register by water users (Table 2.1). A higher level of water use in Kukruse as well as in Alatskivi, Vaabina, and Pärnu probably indicates a leakage in water supply systems.

Income is an important driver of public water use since a higher household income can result in more water use and increased capacity of water equipment, such as showers, toilets, water heaters, washing machines, etc. In 2000, about 88% of Estonian households had a cold water supply through pipes from an external central network. Nearly 86% of households emptied wastewater and faeces into a piped system connected to a public central or a local sewage disposal system or septic tank and 74% used bath (shower) in case the dwelling was equipped with a fixed bath or shower that was connected to a sewage disposal system (Estonian statistics, 2000). Data on toilet types (by flushing volumes), washing machines, dishwashers and alternative water supply and wastewater systems, required for the assessment of sustainability of water use, is not available.

Losses of water through leakage vary a lot in Europe from 50% in Bulgaria and 40% in Slovenia to only 3% in Germany (Chenoweth, 2007). Attempts have been made in recent years to reduce such losses in Estonia. For example, in the Tallinn water supply network the leakage level decreased from about 39% in 1999 to 17% in 2008, which is the same level as in Helsinki. In other Estonian municipalities leakage usually varied between 10% and 30% as an average in 2004, being 20%, 21% and 27% in Pärnu, Tartu and Narva, respectively, but exceeding 70% in the Kohtla-Järve region (Veekasutus, 2004). The data about leakages until 2006 do not cover the entire country and since 2007, no data on leakages from the water supply network are available.

2.2.3 Water exploitation index

The Water Exploitation Index (WEI) is annual total water abstraction per year as percentage of available long-term freshwater resources. Ratio less than 10% shows low water stress. Ratio in the range of 10% to 20% indicates moderate water stress and ratio in the range of 20% to 40% indicates medium-high stress and over 40% high stress (Raskin et al., 1997). The balance between water abstraction and availability is quite critical in many European countries. In Bulgaria, Belgium, Germany, England and Wales non-consumptive uses, i.e. cooling water, raise the WEI over the critical value of 20%. In Italy, Spain, Cyprus, FYR of Macedonia and

Malta consumptive uses, i.e. for irrigation, bring WEI over the limit value of 20%. Denmark, Finland, Sweden, Lithuania and Latvia have low pressure on the water resources, and their WEI is below 10%. Similarly, the WEI is below 4% in Estonia, thus showing low pressure to the water resources (EER, 2010).

2.2.4 Wastewater treatment

In Estonia remarkable changes have occurred since the 1990s - pollution load of BOD, total nitrogen and total phosphorus to the environment have decreased by more than 70%. This decline was partly caused by the economic recession in the beginning of 1990s as well as by water saving measures implemented in both the domestic and industry sectors. A further decrease has been achieved by the implementation of cleaner technologies in production processes, upgrading of the existing wastewater treatment plants, construction of new high-grade facilities and renewal and construction of sewer pipes. Total phosphorus and nitrogen point source load discharged into the recipient water bodies in 2008 were 146 and 1,881 tons, respectively. In 1993 only 13% of the wastewater passed advanced tertiary level biological treatment that includes nutrient (N and/or P) removal. By 2008 the share of the advanced treatment reached almost 80% (Figure 2.2), which is comparable to the level in the Nordic countries.

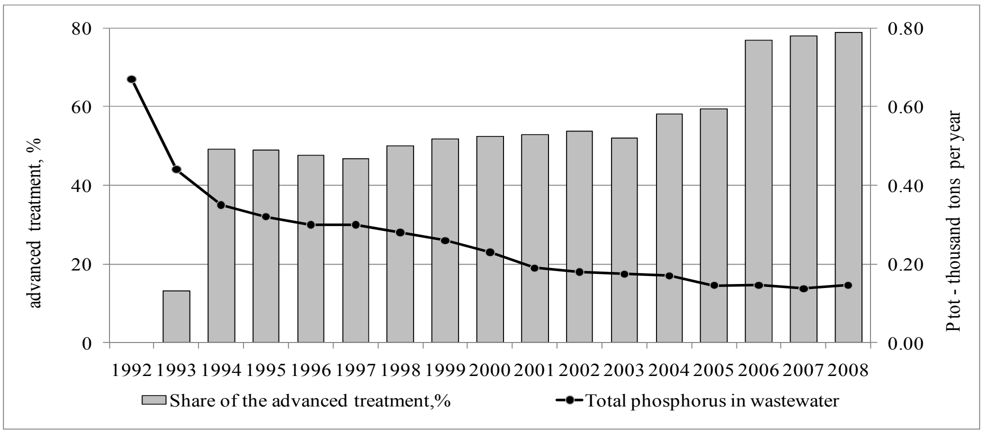


Figure 2.2 Share of the advanced (tertiary level) wastewater treatment and total phosphorus load in Estonia in 1992-2008.

Despite the improved performance of WWTPs the overall nutrient loads, especially for phosphorus, are still fairly high (Paper V).

2.2.5 Water valuation (resource and pollution charge, water and wastewater price)

Both IWRM and WFD aim at the implementation of economic measures in the environmental policy by following the polluter pay principle. Water pricing is one of the measures to promote sustainable water use in the domestic and industry sectors. Water prices can be considered as an instrument for satisfactory water allocation and must be justified in a satisfactory way (Ioslovich & Gutman, 2001).

There are three major indicators in water pricing used in Estonia: water abstraction charge, pollution charge and water price for consumer. The Water Abstraction Charge must be paid for the right to abstract water from a water body or aquifer in the cases when water is abstracted from groundwater over 5 cubic meters per day and from surface water body more than 30 cubic meters per day. Abstraction for generation of hydro energy, irrigation of agricultural land and fish farming is free of charge. The Water Abstraction Charge varies depending on the source of water and nature of water body. Since 1997 charges have been increased constantly by about 10% per year, being as a result 7 to 55 times higher in 2010 compared to 1993. By 2015 a further increase in charges by 1.4 times is foreseen (Table 2.2).

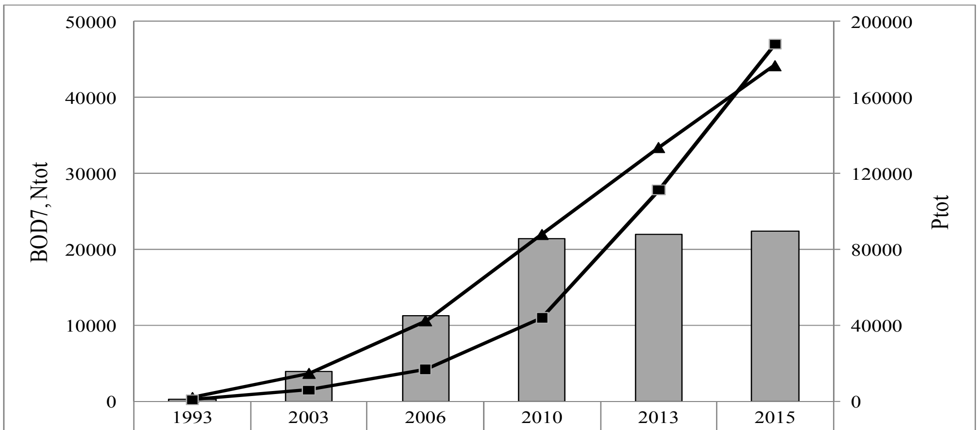
Table 2.2 Water abstraction charge for selected sources of water, EEK per 1,000 cubic meters

Source of water	1993	2001	2006	2010	2015
Water bodies of Tallinn water supply system	20	300	350	440	600
Other water bodies	10	140	230	330	462
Quaternary aquifer (Q)	20	300	480	704	986
Upper- and Middle-Devonian aquifer (D3-2) up to Ordovician-Cambrian aquifer (O-E)	40	400	640	946	1,325
Cambrian-Vendian aquifer (E-V)	60	450	720	1,056	1,479
Use of E-V aquifer for technological needs, except for food production	500*	800	1,290	1,881	2,635
Water pumped from quarries	5	50	150	209	293
Water pumped from mines	5	50	400	583	817
Mineral water for drinking	400	22,000	23,100	28,000	36,000

*1996

The Pollution Charge is applied for discharge of organic matter, phosphorous and nitrogen compounds, suspended solids, sulphates, monophenols, oil or oil products, mineral oil or liquid products obtained from the thermal treatment of solid fuel or other organic matter, wastewater which has a hydrogen ion exponent (pH) greater than 9.0 or less than 6.0 or other substances hazardous to the aquatic environment into a water body, groundwater or soil. The Pollution Charge is not required if substances are used as fertilizers or if they are released into a water body by rain water through a storm water sewer in compliance with the Water Act and the requirements established on the basis of that act.

The highest pollution charge is the pollution charge for discharging monophenols and hazardous substances which are not mentioned in the Environmental Charges Act, into water bodies. The rate for sulphates is the lowest. Pollution charges for all substaces are much higher in 2010 compared to 1993 and are still increasing, except for organic matter that will remain unchanged until 2015 as there are no major problems with the removal of organic matter from the wastewater in Estonia. As regards BOD, the rise was the highest in the time period between 1993 and 2003, followed by a stable charge rate since 2010 (Figure 2.3). Polluters must pay about twice more for phosphorus (Ptot) than for nitrogen and BOD_7.



	1993	2003	2006	2010	2013	2015
BOD7	250	3902	11239	21363	22011	22453
Ntot	500	3682	10604	21988	33441	44225
Ptot	900	5878	16929	43879	111232	187982

Figure 2.3 Pollution charge rates for the emission of one ton of organic matter, total nitrogen and total phosphorus into a water body, groundwater or soil, EEK

The average price of water supply and sewerage, based on the data of approximately 30 waterworks, has increased by almost 40 times during 1992–2009 and has reached 31.4 EEK in 2010. In general the price for business customers has been higher than for domestic customers, but in about one third of the water works, including Pärnu, Rapla, Jõgeva, Kadrina and Haapsalu, the same price for both was established in 2009. In future the price of water for all users will be the same.

3 POLLUTION LOAD TO THE BALTIC SEA

3.1 Previuos study results on nutrient load and source apportionment

Eutrophication enhanced by the input of nutrients still remains a major problem in the Baltic Sea Area. The main sources of nutrients are agriculture, urban areas, industries and air load (Helcom, 2003). Reliable and comparable data on inputs to the Baltic Sea from land-based sources are needed in implementing the objectives of the Helcom Convention by parties in order to develop its environmental policy and to assess the effectiveness of measures taken to abate the pollution in the Baltic Sea catchment area (Helcom, 2004).

According to the Baltic Sea States Ministers of Environment Declaration in 1988, a 50% reduction in anthropogenic load by nitrogen and phosphorus to the Baltic Sea should have been achieved by the year 1995. In Estonia the overall target for the 50% reduction in nutrient loads to the environment was achieved (Paper I).

Table 3.1 Total discharge of anthropogenic nitrogen and phosphorus in Estonia

Discharges source	Load in late 1980s		Load 1995, t/y		Reduction, t/y		Reduction, %	
	Ntot	Ptot	Ntot	Ptot	Ntot	Ptot	Ntot	Ptot
Direct municipal	4,719	291	1,788	106	2,931	185	62.1	63.6
Indirect municipal	1,792	282	881	134	911	148	54.7	52.5
Direct industrial	11,792	44	1,556	20	10,236	24	86.8	54.5
Indirect industrial	731	84	547	31	184	53	25.2	63.1
Fish farms	160	27	38	5	122	22	76.3	81.5
Total point sources	19,194	728	4,810	296	14,384	432	74.9	59.3
Agriculture	30,240	360	12,600	250	17,640	110	58.3	30.5

A remarkable decrease in both N and P load was achieved from point sources (Table 3.1), indicating improved wastewater treatment efficiency and decreased water consumption by industry and households. In 2000 Estonia was responsible for 26,874 tons of total nitrogen and 965 tons of total phosphorus, which was respectively 3.6% and 2.8% of the whole Baltic Sea pollution load (Helcom, 2004). In 2006 the respective figures were 20,412 and 786 tons.

Riverine transport is the most important pathway for the input of nutrients. The results of a study carried out in the Lake Peipsi catchment area showed that during the time period 1995-1998 the lake received annually an average of 20,500 tonnes of nitrogen and 910 tonnes of phosphorus from its basin's rivers (Paper II), the figures being substantially lower than previously reported (Loigu & Leisk, 1996). The Russian Velikaya River alone accounted for approximately 65% of phosphorus and 51% of nitrogen load of the total riverine load. For the Estonian Emajõgi River the respective numbers are 16% for phosphorus and 19% for nitrogen of the total riverine load. All other rivers together contributed the same amount as the Emajõgi River. Atmospheric deposition formed about 2% for phosphorus and 12% for nitrogen. The lake is connected to the Baltic Sea by the Narva River, the largest river in Estonia bordering Russia. More than 65% of the Narva River catchment is situated in Russia.

Point sources accounted for less than 10% of the nitrogen load and approximately 20-25% of the phosphorus load to Lake Peipsi from the whole catchment area. Nitrogen load originating from wastewater made up only 7% of the total river load from the Estonian part of the catchment. More than half of the load comes from agriculture and over 35% from forests and other diffuse sources. Wastewaters contributed about 30% and agriculture nearly 40% of the phosphorus load into the Estonian rivers.

Source apportionment of loads from the Russian part of the catchment showed that 80% of the nitrogen and 70% of the phosphorus originates from agriculture. Point sources account for only less than 10% of the nitrogen and about 20% of the phosphorus load in Russian rivers (Paper II). Sampling results from the Velikaya River upstream of the city of Pskov and downstream from the same city revealed that the concentration of nitrogen in the downstream site was generally higher than in the upstream site. This difference can be attributed to discharges from the city of Pskov. Surprisingly, phosphorus concentrations downstream from Pskov were lower than the corresponding values at the upstream site. The reasons for this unexpected result are not known. Where harmonized methodology is not applied, large differences in the estimates of pollution loads and quality measurements may occur. In Russia, the monitoring of nutrient concentrations in rivers, lakes and point sources does not involve the analyses of total-N and total-P, making the assessment of pollution loads uncertain.

Even though Estonian rivers contribute only about 4% of the nitrogen and phosphorus load (Humborg et al., 2007) to the Baltic Sea it is still possible to take measures to further decrease the nutrient loads from point- and non-point sources. The decrease will be faster when the efficiency of wastewater treatment by introducing high-grade (tertiary) treatment is improved. This measure together with the increased number of people who are connected to wastewater treatment plants will give a rather immediate response (Humborg et al., 2007; Bryhn, 2009).

3.2 Helcom Baltic Sea Action Plan

The ministers of the environment of the Baltic Sea countries adopted an action plan to achieve a good ecological status of the Baltic Sea by 2021 (Helcom, 2007). One of the thematic issues covered by the Baltic Sea Action Plan is eutrophication that requires further reduction of nutrient inputs and introducing the principle of maximum allowable nutrients inputs. The maximum annual nutrient input levels that were agreed are about 21,000 tonnes of phosphorus and 600,000 tonnes of nitrogen. Country-wise annual nutrient input reduction targets were proposed (Table 3.2) and actions should be agreed on not later than 2016.

Table 3.2 Country-wise provisional nutrient reduction requirements agreed by the ministers of the environment of the Member States of HELCOM

Country	Phosphorus (tonnes)	Nitrogen (tonnes)
Denmark	16	17,210
Estonia	**220**	**900**
Finland	150	1,200
Germany	240	5,620
Latvia	300	2,560
Lithuania	880	11,750
Poland	8,760	62,400
Russia	2,500	6,970
Sweden	290	20,780
Transboundary Common pool*	1,660	3,780

** coming from transboundary waterborne pollution originating in Belarus*

Based on the agreed targets possible scenarios for nutrient reduction were developed to assess the efficiency of different measures and the existing or possible future requirements set by national and international legal acts and agreements with regard to waste water treatment.

3.3 Scenarios for reduction of wastewater pollution load

3.3.1 Legal basis and limit values for reduction of wastewater load

The scenarios developed for the reduction of wastewater pollution load take into account four major legal documents containing the requirements for discharging wastewater into water bodies:

- Regulation of the Government of Estonia No 269, 31 July 2001 on the procedure for discharging wastewater into water bodies or soil;
- Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC);

- Helcom Recommendation 28E/5, adopted on 15 November 2007, having regard to Article 20, Paragraph 1b of the Helsinki Convention Municipal Wastewater Treatment;

- Helcom Recommendation 28E/6, adopted on 15 November 2007, having regard to Article 20, Paragraph 1b of the Helsinki Convention.

The purpose of all four documents is to protect the environment from the adverse effects of waste water discharges; however the limit values for outlet concentrations and/or treatment efficiencies differ from each other. Limit values of BOD, phosphorus and nitrogen for wastewater discharges according to the national, EU and HELCOM requirements are presented in Table 3.3.

Table 3.3 Limit values of BOD, phosphorus and nitrogen for wastewater discharges based on the national, EU and HELCOM requirements and depending on the size of sewerage systems.

Para-meter	**PE*→**	**below 300****		**300 – 2,000**		**2,000 – 10,000**		**10,000 – 100,000**		**above 100,000**	
	Scenario↓	min %	C, mg/l	min %	C, mg/l	min %	C, mg/l	min %	C, mg/l	min %	C, mg/l
BOD_7	Estonia					90	15	90	15	90	15
BOD_5	EU					70-90	25	70-90	25	70-90	25
	Helcom		20	80	25	80	15	80	15	80	15
Total P	Estonia					80	1.5	80	1	80	1
	EU					80	2	80	2	80	1
	Helcom		5	70	2	80	1	90	0.5	90	0.5
Total N	Estonia					-	-	70-80	15	70-80	10
	EU					-	-	70-80	15	70-80	10
	Helcom		25	30	35	30	-	70-80	15	70- 80	10

** PE. (population equivalent) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day;** -Helcom Alternative 1*

In Estonia, waste water from small sources of pollution (less than 2,000 PE) must be treated before discharging into water bodies and should correspond to the level required in the water permit while the requirements can not be more stringent than the limit values provided for waste water discharges from sources between 2,001-10,000 PE. The EU requires that urban waste water entering collecting systems from agglomerations of less than 2,000 PE must before discharge be subject to appropriate treatment, which means treatment of urban waste water by any process and/or disposal system which after the discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of the Urban Wastewater Treatment Directive and other Community Directives.

In Helcom region, alternatively, for agglomerations above 10,000 PE the concentration of phosphorus in treated wastewater should not exceed 1.0 mg/l or a

90% reduction should be achieved until 2013. For single family homes, small businesses and settlements up to 300 PE untreated wastewaters must not be led directly to natural water systems in areas that are not connected to sewers.

In general, Estonian regulation is more stringent on phosphorus compared to the EU directive, yet HELCOM recommendations are more stringent on both phosphorus and nitrogen.

3.3.2 Used data and calculation method

The state keeps account over water resources and their status. Account of water resources is kept in the National Environmental Register as water cadastre. The purpose of keeping the state water cadastre is to keep record of the amount, level, quality, use and users of water in Estonia, as well as the long-term holding and issuing of data. The responsible processor of the database is the Ministry of Environment and the authorised processor is the Environment Information Centre (EEIC). The state water cadastre consists of surface water database, groundwater database, marine water database and water use and wastewater database. As regards waste water, the water use database (VEKA) contains: name and location of recipient of sewer outlet; amount, type and level of wastewater treatment; pollution load by the main pollution parameters; sludge data; WWTP data.

In accordance with the Estonian Water Act and Regulation of the Minister of Environment on the procedure for issue and revocation of special water use permits, a water user should possess a permit for special use of water if the limit values on water use exceed the established levels. According to the permit, the water user should keep account over the volume and parameters of the used water and wastewater and organise monitoring following the prescriptions of the environmental authority of the location of special use of water. The data are submitted to county environmental services who forward the required information to the state water cadastre. In Estonia, the total number of units submitting annual water use reports totals about 1,200. After reviewing the relevant EU and Estonian legislative acts, a harmonised divison according to the pollution load with limit values for parameters were chosen for the assessment in Tables 3.5 and 3.6. The basic year for calculations is 2007.

Table 3.4 Division of the pollution loads by PE in 2007

Pollution load	Settlements
≥ 100,000	Coastal (2) - Tallinn, Pärnu. Inland (2) - Narva, Tartu
10,000 – 100,000	Coastal (4) - Haapsalu, Kohtla-Järve, Kuressaare, Sillamäe. Inland (11) - Maardu, Kehra, Ahtme, Rakvere, Põltsamaa, Põlva, Viljandi, Valga, Võru, Rapla, Paide
2,000 – 10,000	Coastal (5) - Loksa, Paldiski, Aseri, Kunda, Keila. Inland (18) - Kose, Jüri, Loo, Kadrina, Tamsalu, Tapa, Kohila, Jõgeva, Väike-Maarja, Räpina, Elva, Tõrva, Otepää, Türi, Kilingi-Nõmme, Märjamaa, Vändra, Kärdla
< 2,000	Other: Pärnu-Jaagup, Järva-Jaani, Järvakandi, Halliste, Taebla, Tori, Roosna-Alliku, Karksi-Nuia, Abja-Paluoja, Vastsemõisa, Toila etc

The reduction scenarios are based on three (EE, EU, Helcom) limit values and were developed by the author by carrying out accounting separately for every PE class and additionally within every class for all wastewater treatment plants (WWTP).

Table 3.5 Limit values for wastewater discharges used in assessment

Para-meter	PE → Scenario↓	below 2,000 mg/l	2,000 – 10,000 mg/l	10,000 – 100,000 mg/l	above 100,000 mg/l
Total P	EE	1.5	1.5	1	1
	EU, EE	1.5	2	2	1
	Helcom, EE	1.5	1.0	0.5	0.5
Total N	EE	-	-	15	10
	EU	-	-	15	10
	Helcom	35	-	15	10

Considering some recent developments − the Helcom Baltic Sea Action Plan pollution load reduction values, the fact that according to the Water Act all Estonian water bodies are defined as pollution sensitive, and changes in wastewater treatment technologies − more strict limit values for WWTPs with the load below 2,000 were used. For total phosphorus it equals 1.5 mg/l and for total nitrogen 35 mg/l (Table 3.5). Cooling water discharges and waters pumped out from mines and quarries were excluded from the assessment. Pollution load in the outlets of the WWTPs was calculated either by multiplying discharges to the measured annual mean concentrations in 2007 or by limit values for PE classes when the measured concentrations were above these levels.

3.3.3 Results

Wastewater treatment in 2007- baseline scenario

In 2007 there were 41 settlements in Estonia with the pollution load exceeding 2,000 population equivalents (Table 3.4). About 70% of the Estonian population reside in these urban areas and 92% of them use the services of a public sewerage system. 72% of the total population of Estonia is supplied with a public sewerage system. In Estonia domestic and industrial wastewaters are usually treated together in urban municipal wastewater treatment plants. The number of industries with separate treatment facilities is limited. The amount of waste water originating from settlements of more than 2,000 PE forms almost 90% of the discharge in Estonia (excl. mine and cooling water). In 2007, pollution load by organic matter BOD_7 was about 72%, suspended solids 77%, total phosphorus 81% and total nitrogen 75% of the total load. Most of the wastewaters requiring treatment go through biological and/or biological-chemical treatment. In 2007, 84.4 million m^3 of wastewater were treated with the combined biological-chemical method; 55% of it was treated at the Tallinn WWTP. 23 million m^3 of wastewater were handled biologically (secondary treatment). Only about 1% of wastewater was released to the environment untreated (excluding cooling and mining water). The efficiency of BOD_7 removal is, as a rule, over 80%, and reached on the average as high as 96.5% in WWTPs with load over 2,000 PE in 2007. The efficiency of phosphorus removal in most of the bigger WWTPs is between 70% and 98%. As regards nitrogen, the treatment efficiency is much lower (Tables 3.6 and 3.7).

Table 3.6 Wastewater treatment efficiency in settlements with pollution load over 10,000 PE in 2007

Settlement	PE	Recipient	Treat-ment level	BOD_7, %	Ntot, %	Ptot, %	Construction year	Last renovation year
Tallinn	> 100,000	coast	III*	98	75	85	1981,84, 93,98	2004
Narva	> 100,000	inland	III*	96	83	89	1967	2005
Pärnu	> 100,000	coast	III*	98	87	94	1980, 1991	1996
Tartu	> 100,000	inland	III*	97	74	89	1996	2003
Ahtme	10 -100,000	inland	II	90	68	83	1974	2008- K-Järve
Kehra	10 -100,000	inland	II	96			1977	2007
K-Järve	10 -100,000	coast	II	93	66	14	1978, 2009	
Kuressaare	10 -100,000	coast	III*	98	76	96	1991, 2001	
Põltsamaa	10 -100,000	inland	III*	99	82	90	1982	2003
Põlva	10 -100,000	inland	III*	99	96	98	1982	1998
Rakvere	10 -100,000	inland	III*	99	86	97	1990	2004
Sillamäe	10 -100,000	coast	III*	97	70	86	1981(78)	2000
Viljandi	10 -100,000	inland	III*	99	85	94	1978, 2005	
Haapsalu	10 -100,000	coast	III*	96	30	94	1982, 1997	2001
Maardu	10 -100,000	coast	II	98	90	93	1978	
Paide	10 -100,000	inland	III*	94	77	76	1978	1996
Rapla	10 -100,000	inland	III*	97	90	99	1982	1998
Valga	10 -100,000	inland	III*	99	91	98	1977, 2001	2004
Võru	10 -100,000	inland	III	96	37	95	1986	1997

** N and P removal*

Table 3.7 Wastewater treatment efficiency in settlements with pollution load between 2,000 and 10,000 PE in 2007

Settlement	PE	Recipient	Treat-ment level	BOD_7, %	Ntot, %	Ptot, %	Construc-tion year	Last renova-tion year
Aseri	2 - 10,000	coast	II	92	55	63	1989	
Elva	2 - 10,000	inland	II	98	33	79	1976	2003
Jõgeva	2 - 10,000	inland	III*	96	90	97	1977, 2001	
Jüri	2 - 10,000	inland	II	97	61	75	1985(3)	2007
Kadrina	2 - 10,000	inland	III*	99	79	95	2000	
Keila	2 - 10,000	inland	III*	98	82	98	1979,2001	2007
Kilingi-Nõmme	2 - 10,000	inland	III	95	51	77	1995	2008
Kohila	2 - 10,000	inland	III*	93	69	67	1985, 2007	
Kose	2 - 10,000	inland	III	97	81	75	1979	1999
Kunda	2 - 10,000	coast	II	96	85	83	1975	2008
Kärdla	2 - 10,000	coast	III*	99	87	94	1996	2009
Loksa	2 - 10,000	coast	III	95	37	68	1986, 2005	
Märjamaa	2 - 10,000	inland	III	94	48	70	1976,1999	2009
Otepää	2 - 10,000	inland	II	99	72	86	1996	
Paldiski	2 - 10,000	coast	III*	96	53	62	1957, 2007	
Räpina	2 - 10,000	inland	II	85	79	59	1985	2009
Tamsalu	2 - 10,000	inland	III*	99	85	95	1973, 1998	
Tapa	2 - 10,000	inland	III*	99	84	78	1997	
Türi	2 - 10,000	inland	II	97	83	93	1996	2008
Väike-Maarja	2 - 10,000	inland	III*	98	94	98	1974	2000
Vändra	2 - 10,000	inland	II	97	94	69	1982	1999

** N and P removal*

Point source load scenarios

In 2007, the total wastewater load to inland surface water bodies and directly to the sea was about 1,400 tons of nitrogen and 130 tons of phosphorus, not considering cooling and mines waters. Direct discharges to the coastal waters formed 55-60% of the total load of nitrogen and phosphorus. The rest was discharged to inland water bodies, mostly to rivers.

As expected, the overall reduction of nutrients is higher when the Helcom recommendations are followed. Point source load of phosphorus can be reduced by more than 50% when following the Helcom recommendations. A decrease of about 25% can be achieved by following all the Estonian regulations and the load will be about 20% lower when the relevant EU directive are implemented (Figure 3.1). The reduction levels of total nitrogen are equal when following the Estonian and EU regulations, however somewhat lower compared to the Helcom recommendations (Figure 3.2).

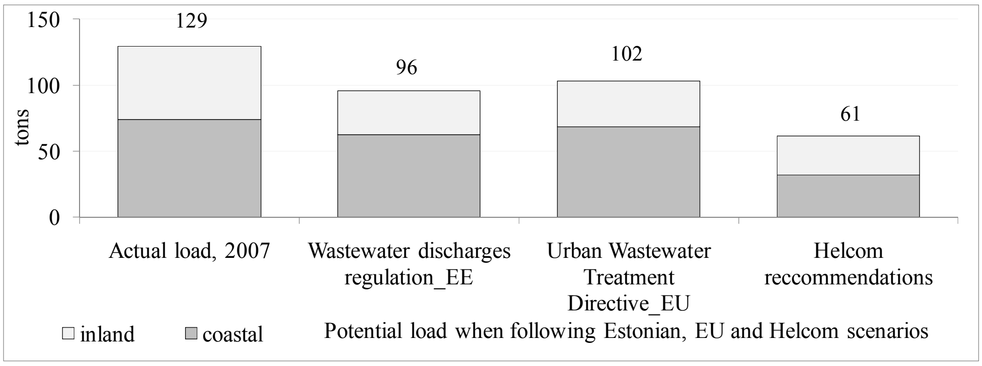


Figure 3.1 Total phosphorus actual and potential load according to Estonian, EU and Helcom scenarios in 2007

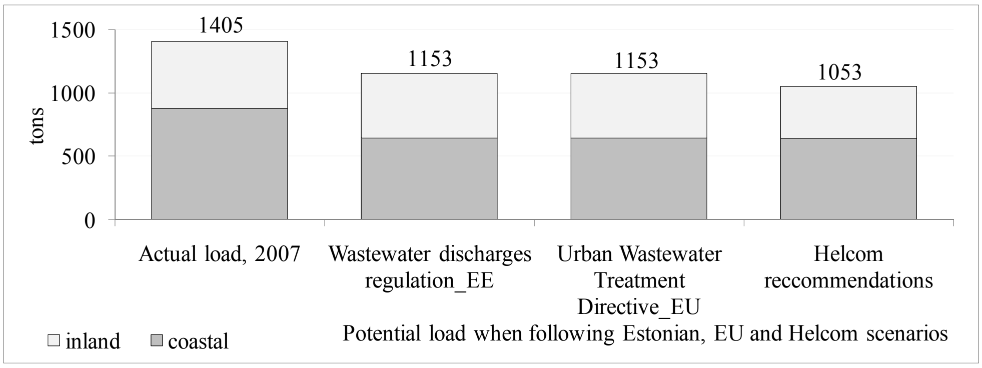
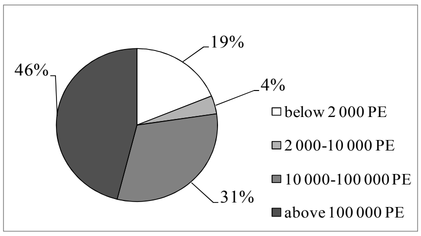


Figure 3.2 Total nitrogen actual and potential load according to Estonian, EU and Helcom scenarios in 2007

The division of point load of phosphorus and nitrogen among settlements of different size classes is quite similar (Figure 3.3). Most of the load originates from the four larger towns: Tallinn, Tartu, Narva and Pärnu (in total 600,000 inhabitants). The share of point load from the settlements between 2,000 and 10,000 PE is the lowest (Figure 3.3). It can be explained by the relatively low number of inhabitants (ca 90,000) and limited industrial activity in addition to the rather well funcioning WWTPs due to renovated or new plants. Since 1999 seven new WWTPs were constructed and 10 were renovated in settlements of this size (Table 3.7). About 230,000 inhabitants lived in settlements with pollution load between 10,000 and 100,000 PE in 2007. The share of nitrogen load from these settlements is about 30% and phosphorus load about 20%, which is quite high. Most of the WWTPs were constructed in the time period between 1974-1986 and have been renovated recently. Four of the WWTS were constructed after 2000, which has had a favorable effect to the nutrients removal efficiency. Discharges from the smallest WWTPs with the load below 2,000 PE are relatively high and formed 19% of the overall annual nitrogen and 25% of phosphorus load (Figure 3.3). Reliablity of these results is doubtful because there is no complete information in the national register for small WWTPs and annual reports are incomplete with many gaps about the treatment efficiency. Wastewater volumes and loads entering WWTPs are not measured either.



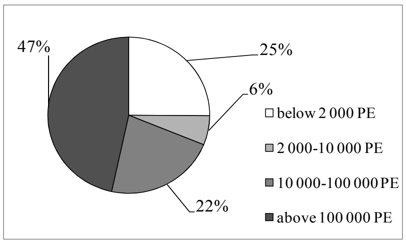


Figure 3.3 Total phosphorus (left) and nitrogen (right) from point sources in 2007, tons

A further decrease in phosphorus load is possible if the maximum permissible allowed phosphorus concentration in the outlet of large WWTPs (PE over 10,000) is equal to or lower than 0.5 mg/l (Figure 3.4). The Tallinn WWTP could contribute the most to the reduction of phosphorus − by about 25 tons. The foreseen reduction in the WWTPs with load below 2,000 PE is about 18 tons; this decrease will take place on account of discharges to inland surface water bodies. A possible decrease from the settlements with load of 10,000 to 100,000 PE is about 16 tons. The possibility for a further decrease in P load from settlements with 2,000 – 10,000 PE is rather limited due to the already achieved relatively high phosphorus removal efficiency (Table 3.7, Figure 3.4).

The largest reduction of nitrogen can be achieved in settlements with pollution load between 10,000 – 100,000 PE, exceeding twice the category of more than 100,000 PE (Figure 3.4). In both categories most of the reduction is possible from direct discharges to the sea. Total nitrogen reduction efficiency of at least 30% could be gained in all WWTPs with load between 2,000-10,000 PE. Most of the settlements in the category below 2,000 PE discharge into inland surface water bodies. Nitrogen removal efficiency for these small settlements is not yet regulated in Estonia.

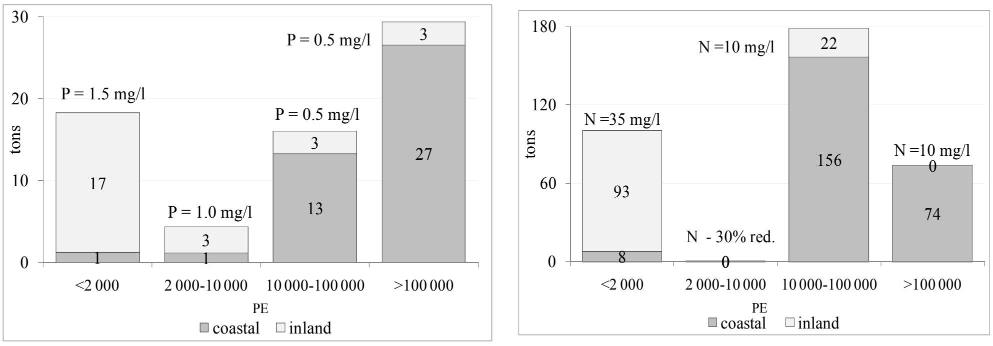


Figure 3.4 Potential for total phosphorus (left) and nitrogen (right) reduction in Estonia by PE classes

Comparison of the two major catchments: the Gulf of Finland, including Lake Peipsi basin and the Gulf of Riga, including Väinameri, revealed that approximately 90% of phosphorus and nitrogen originate from the Gulf of Finland catchment area. Most of the load is discharged directly to the sea. Contrary to this, most of the nutrients in the Gulf of Riga basin are discharged into inland water bodies (Figures 3.5 and 3.6).

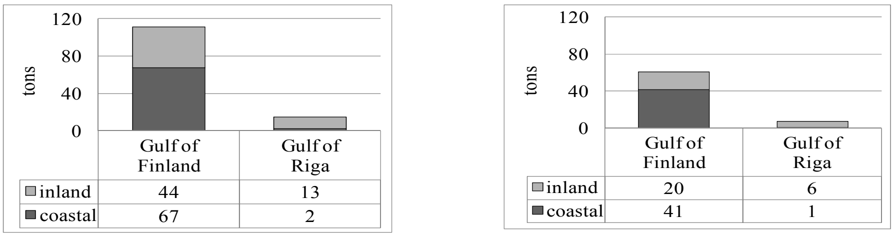


Figure 3.5 Total phosphorus pollution load and potential reduction by catchments

The share of Lake Peipsi basin in the Gulf of Finland catchment is about 180 tons (15%) of nitrogen and nearly 20 tons (18%) of phosphorus load. Most of the load enters into Lake Peipsi via rivers. The possible reduction for nitrogen and phosphorus into Lake Peipsi is about 16 and 8 tons, respectively, when following the most stringent scenario. A higher phosphorus reduction can be achieved by reduced input from inland sources and nitrogen reduction in the coastal areas of the Gulf of Riga (Figures 3.5, 3.6).

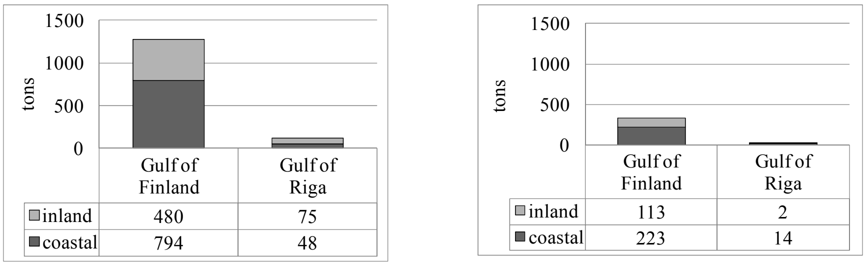


Figure 3.6 Total nitrogen pollution load and potential reduction by catchments

The potential reduction of phosphorus is the highest in the category of load above 100,000 PE, including direct discharge from Tallinn (25 tons) and discharge to the Narva River from the town Narva (3 tons). A decrease from settlements between 10,000 PE and 100,000 PE (Kohtla-Järve, Sillamäe, Maardu, Ahtme) could contribute the most to a decrease in nitrogen load. The regional WWTP in Kohtla-Järve (deep outlet into the sea) contributes the most in the category of 10,000-100,000 PE. A possible decrease in nitrogen load from Tallinn accounts for 73 tons. A further reduction of nitrogen load from WWTPs with load between 2,000 and 10,000 PE is not foreseen, since the required_nitrogen removal efficiency of 30% has been already achieved in all WWTPs. Most of phosphorus (12 tons) and nitrogen (91 tons) reduction should be achieved by reducing their load into inland water bodies in the category below 2,000 PE (Figure 3.7).

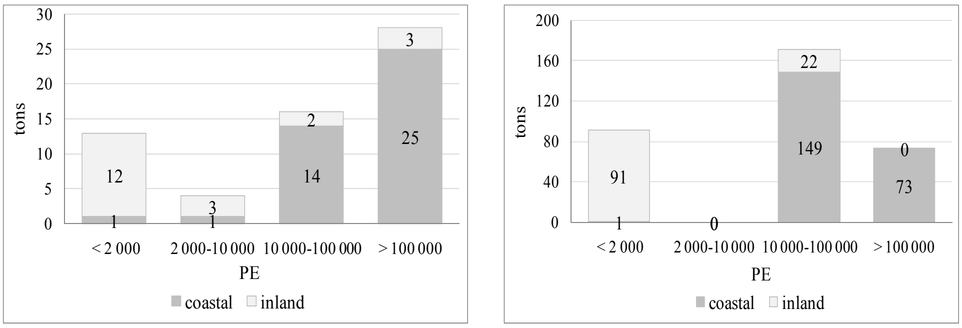


Figure 3.7 Total phosphorus (left) and nitrogen (right) potential reduction in Gulf of Finland catchment area, tons

In all PE classes, most of the potential reduction of phosphorus in the Gulf of Riga catchment area can be achieved from inland sources and of nitrogen from direct sources to the sea (Figure 3.8). The largest decrease in both phosphorus and nitrogen is possible in the category of settlements with pollution load below 2,000 PE. A possible reduction of nitrogen load in Haapsalu, representing a settlement with load between 10,000 PE and 100,000 PE, is the most remarkable. No decrease is foreseen in the category with pollution load between 2,000 and 10,000 PE.

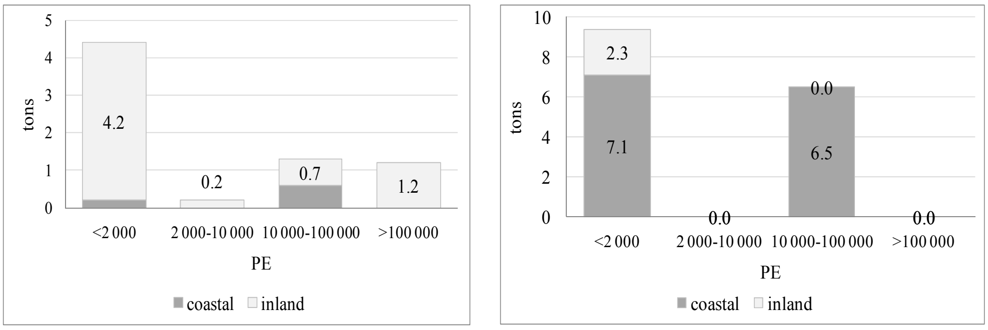


Figure 3.8 Potential for reduction of total phosphorus (left) and nitrogen (right) load in the Gulf of Riga catchment area, tons

The study results show that about 20% of phosphorus and 25% of nitrogen could be eliminated from the total load discharged from Estonia directly to the Baltic Sea, assuming that effluent values of wastewater are in agreement with the most stringent limits (Table 3.8). Actual load can even be lower because real concentrations in the outlet are somewhat lower compared to the limit values. The whole load to inland water bodies will not reach the sea due to retention of nutrients in river systems. This aspect should be taken into account when assessing the total river load to the Baltic Sea. A more precise assessment of the retention capacity of Estonian rivers requires further investigations.

Table 3.8 Comparison of reduction target values of the Baltic Sea Action Plan and potential for reduction of wastewater load in Estonia

	Reduction	**Total phosphorus**	**Total nitrogen**
Baltic Sea Action Plan	Total	220	900
Potential for wastewater reduction in Estonia	Coastal	42	238
	Inland	26	114
	Total	68	352

My study results confirm that the focus for reduction, at least in case of the Baltic Sea, should be on phosphorus, as has been proved by Boesch et al. (2006) and Ulen & Weyhenmeyer (2007). Despite of the fact that a further reduction of phosphorus point source load is possible to some extent, most of the nutrients load should be diminished from diffuse sources, e.g. agriculture, etc.

4 STATUS OF WATER BODIES IN ESTONIA

4.1 Legal basis for assigning water quality classes

Assessment of the state of water bodies is the basis for compiling programs of measures for watershed management and for evaluating and upgrading the legal basis (e.g. defining limit values). The assessment of the state of water bodies is based on the general procedure provided by the EU WFD and the two relevant regulations on surface and groundwater bodies of the Minister of the Environment of Estonia (RTL, 2009 & RTL, 2010)

The evaluation of the ecological status of surface water bodies focuses on biological, hydromorphological and physical-chemical quality indicators. The main emphasis is on biological quality elements, such as phytoplankton, phytobenthos, macrophytes, zoobenthos and fish. Hydromorphological conditions include water regime, flow rate, dams, rivers slope and substrate, width and depth variability. The extent of the riparian area, as a habitat for flora and fauna and its potential for protection of the river from non point pollution, are all important aspects of ecological quality. Physical-chemical indicators include water temperature, oxygen content, transparency and nutrient content. The overall quality is determined by the worst biological quality element, expressed in a five-level classification system from high to bad status.

4.2 State of the water bodies

There are 15 primary groundwater layers identified in Estonia and the status of each is evaluated according to various quantitative and qualitative indicators, i.e. the content of dissolved oxygen, ammonium-ion, nitrate-ion, pesticides, etc. The status of most groundwater bodies in Estonia is good, except for the groundwater body of the Ordovician Ida-Viru oil shale basin and the Silurian-Ordovician groundwater bodies with unprotected groundwater, where deviation from limit values was observed (EER, 2010). The quality of the upper groundwater layers of the Pandivere and Adavere-Põltsamaa nitrate vulnerable zone (7% of the Estonian territory) exceeded the limit values for nitrates in 2008.

None of the coastal water bodies met the requirements of “high” quality class, while four water bodies were classified as “good” and one as „poor“. Other 11 were identified as “moderate”, several of them due to the general status of the Baltic Sea.

Most Estonian lakes are in the “good” or “moderate” status. The ecological status of Lake Peipsi and Lake Pskov has worsened in recent years, due to eutrophication and excessive phosphorus load (Paper II). Ten years of monitoring of Lake Võrtsjärv show that the water body belongs to the “good” quality class. Half of the smaller lakes (about 150) have good status, one third moderate status, 17 lakes have high status, and 9 lakes poor status.

To estimate the status of the 639 identified river water bodies monitoring data (69% of water bodies) and expert judgement on pressure factors were used. The overall status was determined based on the poorest biological quality element or according to the combined water quality status. About 74% of water bodies were in good status, 22% in moderate, 3% in poor and 1% in high status (EER, 2010).

4.3 Nutrients in rivers

The reliability of the assessment of the status of water bodies is directly dependant on the quality and scope of the environmental monitoring system and has thus a significant effect on the quality of water-related policies, activities and planned measures as well as the development of suitable aquatic environment standards (Paper III). Routine monitoring should be carried out at appropriate times with sufficient frequency and should involve detection of valid parameters. This in turn requires adequate financing of the monitoring systems by governments, local authorities and water users themselves. An assessment of changes in nutrient concentrations in Estonian rivers as a response to improved wastewater treatment and substantial reductions in the use of fertilisers and number of livestock during the past 15–20 years was made (Paper VI). The statistical analysis covered time series of 53 sampling sites on 40 rivers and streams in different hydro-geographical regions and varying human pressures. The results indicate a statistically significant downward trend in nitrogen concentration in 34% of all sampling stations during the studied period; only very few showed an upward trend (Figure 4.1). The concentration of phosphorus decreased only in 25% of the locations. In 13% of the locations the concentration of phosphorus was even increasing. In the majority of rivers, concentrations were fairly stable throughout the studied periods.

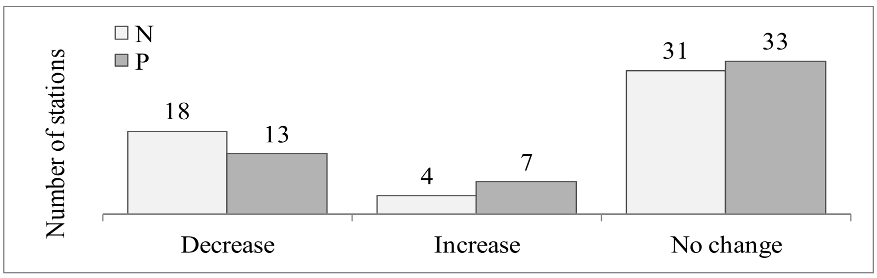


Figure 4.1 Trends in nitrogen and phosphorus concentrations in Estonian rivers in 1984-2006

The study results revealed that statistically significant downward or upward trends for TN and TP were detected only for relatively smaller rivers with catchment areas not exceeding 2,000 square kilometers. Moreover, a decreasing trend of TN has been characteristic both for rivers with a high share of agricultural land in catchments and in catchments dominated by forests and wetlands. These results raise a question whether the monitoring system provides sufficient information for decision makers for implementing measures to improve water quality and to decrease pollution load. The assessment of the efficiency of monitoring system of diffuse pollution from agriculture to support the implementation of the WFD and the Nitrate Directive in Estonia revealed that the existing surface water quality monitoring network provided only limited information to select between different management options for implementing action programmes for the NVZ and the river basin management plans (RBMP) under the WFD (Paper V).

Nevertheless, it is obvious that several rivers have responded: (i) to improved waste water treatment efficiency, especially in larger cities, (ii) to the decrease in the area of agricultural land, (iii) decreased use of organic and inorganic fertilisers and livestock numbers; (iv) increased proportions of abandoned land at the expense of cultivated areas; (v) better farm management practices. Agriculture remains the main source of diffuse pollution of inland surface waters, comprising 62% of TN and 43% of TP in 2004 (Oras et al., 2006). It is very likely that diffuse nutrient losses from agriculture will become even more important due to the improvement of industrial and municipal waste water treatment, especially for small settlements.

The nutrient policies require an integrated approach embracing the whole nutrient cycle (Report..., 2009). The principal lessons for Estonia, and indeed for the wider EU, is that due consideration must be directed toward the establishment and longer-term maintenance of suitably targeted (spatially and temporally) monitoring strategies. Given the scope of inter-annual variations in diffuse pollution fluxes, source apportionment should be more widely adopted to assess the potential impact of mitigation measures under the WFD and ND. Implementation of the WFD and other related directives will closely rely on appropriate monitoring programmes. However, the existing monitoring network and associated techniques in Estonia potentially fail to adequately capture the spatio-temporal variability in both point- and non-point sources pollution.

4.4 Further actions for assessment of water bodies

According to the WFD a goal has been set to achieve a good status of all water bodies by 2015. As the state resources to conduct national environmental monitoring of all water bodies are limited, the impact assessment should be done by imposing the obligation to monitor the recipient status on water users. According to the Environmental Monitoring Act an undertaking must carry out environmental monitoring at its own expense in the area affected by its activities or by pollutants discharged into the environment as a result of its activities for the undertaking's own purposes,to the extent and pursuant to the procedure determined in the natural resources exploitation permit or the pollution permit issued to the undertaking pursuant to law (RT I 2009, 49, 331).

By the Water Act water users are required to estimate the amount and characteristics of the water used and the wastewater in the case of special use of water, and organise monitoring of the effluent under the conditions and pursuant to the procedure determined in the permit for the special use of water. A person who arranges an activity that adversely affects water quality is required to observe the water status in the area affected by the activity (RT,2010). Special user of water is required to organise the analysis of samples for checking the limit values of waste water pollution indicators or treatment levels of waste water. Samples must also be taken by attested samplers and analysed in accredited laboratories as provided in the legislation in force in Estonia. In Estonia all environmental permits are available in internet. The inventory of permits for special use of water in settlements with a pollution load exceeding 2,000 PE at Viru-Peipsi sub-basins in Estonia revealed that monitoring requirements of WWTP outlets according to the Regulation of the Government (RT I 2010, 13, 70) were available only for 12 out of 17 settlements (Paper III).

However, the permits for special use of water of five water undertakings, serving the settlements of Väike-Maarja, Kunda, Rakvere, Ahtme and Kohtla-Järve, are not available in internet.

Monitoring of the quality of the recipient water body is required in four permits out of twelve, the required sampling frequency being only from two to four times per year. The list of indicators included only taxable pollutants: BOD7, Ntot, Ptot, etc. Monitoring both upstream and downstream from the wastewater discharge is required only in Narva and Võru. In 2010, the inventory of permits for special users of water in Viru-Peipsi sub-basins was repeated. The results show that the situation has not changed during the five years. Therefore a list of the following recommendations to improve the situation was proposed:

- a clearly defined requirement for taking samples of the wastewater entering wastewater treatment plant and determination of pollution load in this water should be added to the permit;
- the requirement to conduct monitoring of both upstream and downstream of recipient should be specified, and the indicators to be determined and the monitoring frequency should be at least the same as for pollutants discharged from pipe-end.

5 DECISION SUPPORT SYSTEMS

Well organised and structured databases as well as efficient and comprehensive analytical tools including modelling are needed for decision making when implementing the WFD and aiming to achieve sustainable water use in river basins and Integrated River Basin Management (IRBM) (Gourbesville, 2008). These decision support systems involve executive information systems, support systems, geographic information systems, online analytical processing, etc. (Mysiak et al, 2005). All information concerning water bodies, such as hydrology, hydrogeology, water quantity and quality, economic, ecological, and environmental data as well as historical data and forecasts with both time-series and spatial distributions should be collected and treated in an integrated, analytical framework. Geographic information system (GIS) is a tool which helps to achieve comprehensive information support and represents river basins in the real world with consideration of spatial dimensions including the geography and topology (McKinney et al, 1999). Thematic modelling, simulation and visualisation tools are needed to prepare and support the decisions that have to be taken for integrated water management at sub-river basin level (Usländer, 2005).

5.1 Thematic modeling

Environmental processes are complicated, thus not easy to model. Moreover, knowledge about the issue is still incomplete, thus there is a need to take into consideration all the available data, to effectively reveal the knowledge about the processes, and to distribute it among all actors involved in the process of environmental management (Cortes et al., 2001). Also, public participation and socio-economic considerations become more important within the planning and decision making process (Dietrich & Funke, 2009).

There are different model systems that have been developed to integrate several domains and themes and can be used also by non-specialist users. The systems emerged from linking the existing models, expert rules, databases and other tools and developing the means to calculate or visualize the effects of different management options (Gourbesville, 2008). The first task when using a model is to find the appropriate model or models because for similar tasks many different models have been developed. The reason why there are so many models is found in the specification of models - a model is originally simplified, a modification reflecting the important sides of the chosen purpose. In a reality based model it would be necessary to describe all the original connections but we lack this knowledge for somewhat more complex systems. And even if we tried to reflect all the knowledge currently available in a model, we would not be any closer to the objective. These complex models demand basic data of a precision which cannot be collected. Thus, when creating a model, the primary task is to simplify, clarifying the important characteristics and connections. We need to determine what is important and what is not important for the purpose of the work, as well as usable data. This also answers the question why there is no single comprehensive model for solving similar problems and why there are many new models responding to different data needs.

As an example of the application of a water quality model a Qual2K and the catchment model Wennerblom were linked and applied to simulate the effect of organic matter and nutrients emissions from point and non-point sources on water quality in the Pärnu River Basin.

5.1.1 Linked model system on the Pärnu River Basin

To achieve the goals set by the WFD it is necessary to review the current situation of water bodies in Estonia, make a summary of the pollution load and to work out water management plans which would bring the desired results. Knowing that there are over 6,000 water bodies in the Estonian Environmental Register, it is obvious that it is not possible to give an exact overview of the condition of Estonia's inland and coastal waters just by using water samples and measuring results. Moreover, nature is so versatile that a sample showing the condition in a certain place at a certain time cannot characterize the same body of water at a different time. Therefore it would be quite impossible to analyze the influence of a planned activity by measuring since that specific situation (to be analyzed) does not yet exist.

For the Pärnu River basin, about which there is scarce national monitoring data, a model aimed at creating software to evaluate surface water quality in all parts of the river basin was created. For creating the software the following important requirements were taken into account: load originating from the catchment, point sources load, processes that take place in water bodies, usage of national monitoring data input, customizing automatic installation of the system, storing the results in the database and visualizing them (Paper IV).

In creating this software the load from the catchment was calculated by using the Wennerblom (Lindström et al., 2000), also known as the Alvsborg model. A stream water quality model Qual2 was used to describe river processes (Chapra & Pelletier, 2003). The calculations are first done with the Wennerblom model and then the results of the Wennerblom model are used as initial data for the Qual2K model. The integration of models and user interface has been developed by the Delphi programming environment and enables to ensure data input and solved versions preservation, as well as model management and exchange of data between models. This integrated model enables to give estimated assessments of the catchment of phosphorus and nitrogen from watersheds, to assess water flow and water quality in fixed-site conditions and to compare different burden-scenario influences.

Results and conclusions

The main outcome of this work is a tool that integrates the two models, uses a database for initializing the models and allows visualizing of results in the Pärnu River basin (Paper IV**)**. This tool enables the combination of different models and allows:

- automatic formation of a model calculation scheme (QUAL2K);
- automatic estimation of river flow rates in every segment (QUAL2K);
- linking of the models with databases (automatic assimilation of up-to-date data for the models input and storing the calculation results).

In general the results of the linked model showed quite a large variation in nutrient loads and concentrations from different sub-basins (Figure 5.1), emphasizing the need to keep a rather detailed structure of land-based pollution models.

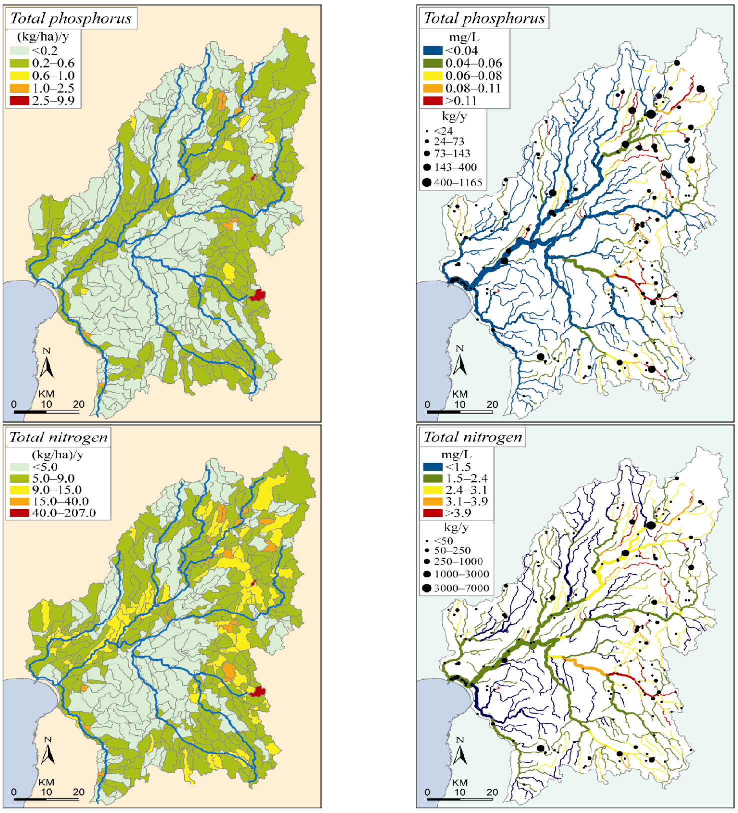


Figure 5.1 Modelled area specific loads and concentrations of phosphorus (upper) and nitrogen (lower) in the Pärnu River catchment area

5.2 Water resources knowledge base – data management

A reliable data collection, handling and reporting system that reflects priorities and societal demands of public and environmental authorities as well public interest, organised into an information system on the national level is an important tool giving up-to-date information into the hands of water specialists, thus enabling a better understanding and more consistent decisions in water management. In Europe, the development of Environmental Information Systems for the water domain is heavily influenced by the need to support the processes of the European Water Framework Directive (Usländer, 2005).

In Estonia several environmental data information systems, including water media, have been developed since 1999, such as the Estonian Nature Information System, the Environmental Permit Information System (Paper III), registers for water use, waste and air pollutants. An essential change in the management of environmental data in connection with the environmental register came in force in 2007 on the basis of the Environmental Register Act. The Act specifies consolidation of national environmental registers and other data collections for better connection of data in time and space (EEIC, 2001). The Environmental Register with its thematic sub (cohesive) information systems and geoinformatics technology is a tool for environmental authorities for managing the environment and preparing their decisions but also the basis for sharing information with professionals, dissemination among the public and national reporting.

There are 110 national reporting items in the water sector in Estonia that have to be reported to different international institutions, i.e. 46 items to Helcom, 51 to the European Commission, 7 to the European Environment Agency (ROD, 2010). The Estonian Environment Information Centre of the Ministry of Environment (EEIC) plays a crucial role in collecting and providing water environment information. Together with the Environmental Register and the linked Nature Information System the EEIC is responsible for collecting, processing, analysing and aggregating the data on Estonian nature, state of the environment, and the factors influencing it. The EEIC is also responsible for reporting the necessary data related to the EU directives, i.e. the WFD and other international obligations, to the European Environment Agency (EEA), EUROSTAT, the European Commission, UNEP and other international institutions.

Assessment of the existing information systems and data requirements shows that data flows are incomplete. Some important links between modules are missing and the agility of the existing information systems is not sufficient enough to absorb the increasing complexity and heterogeneity of data and information needed for decision making in a fast changing legislative environment. Data availability with regard to non-point sources, drinking and bathing water quality is the most problematic. The necessary new pathways and system parts are described in Figure 5.2. There is a great need for harmonization and integration inside and between the existing information systems. One of the tasks is to stop duplicating data collection in water user annual reports, charge modules and water permits. Establishing links between modules in the system and databases outside the current system is another issue.

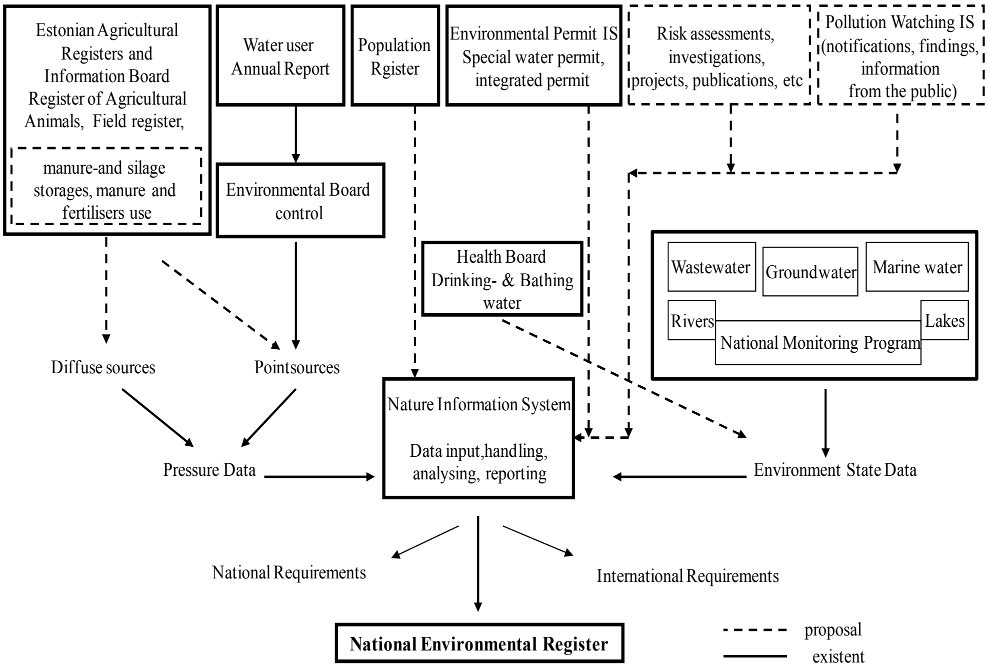


Figure 5.2 Proposal to improve the Estonian Water Information System and data flows

To support and facilitate the integrated water management processes and comprehensive decision making the author proposes to amend and join all the existing different databases and information systems into one comprehensive, collaborative Estonian Water Information System (EWIS) portal, as presented in Figure 5.3. This system will promote the compiling of river basin management plans, development of measures and implementation of WFD and reporting on other national and international obligations.

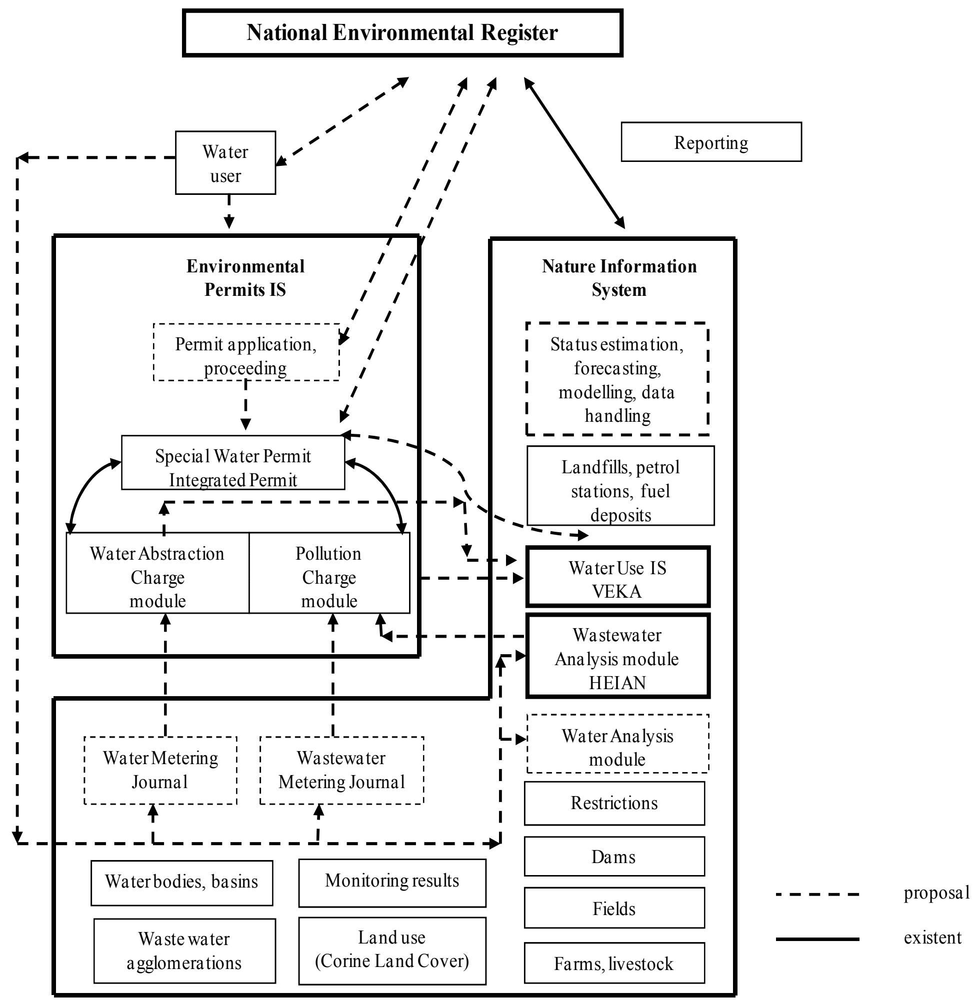


Figure 5.3 Proposal for the structure of the Estonian Water Information System

The EWIS should also be able to:

- provide organisational and technical solutions to cope with networks of systems that require interoperability;
- integrate scattered information located in different institutions as soon as it is available, irrespective of its sources and formats, to reduce the workload and speed up the decision-making process;
- develop IT solutions for the integrated analysis of information necessary to elaborate reporting on various national and international purposes;

- develop IT solutions to link and integrate water basin models with the GIS tool to use the system's data and work in cooperation with the whole system (Paper IV);

- secure one-off data collection, for reusing the existing information, without a need to reprocess it and without a need to duplicate data sets for the optimal use of provided information;

- apply e-water permit, management based on application for and issuing of permits as well as process proceeding on-line;

- enhance public and stakeholders commitment to the decision process, implement targeted reporting to the public and stakeholders, allow for public consultation and participation to receive continuous feedback of the implementation process.

A single web-based multi-system and multi-user oriented entry point should be used when integrating all the dimensions of the system (Gourbesville, 2008).

CONCLUSIONS

- There are no major problems with the quantity and availability of water resources in Estonia. However, regionally there can be difficulties to guarantee water of the required quality to different users. Our knowledge on the status of water bodies is still insufficient. Therefore, a better monitoring system is essential. More frequent and problem oriented monitoring is needed, especially for groundwater outside the nitrate vulnerable zone. Definition of good status of water bodies requires additional monitoring, e.g. to determine natural background conditions. Despite of the requirements set by the Estonian legislation, many environmental permits do still not include an obligation for self-monitoring by water users to ensure that concentrations of polluting substances in the receiving water do not exceed the EQS, especially when it has been decided not to run an environmental impact assessment. Self-monitoring programmes are, as a rule, limited to take samples at monthly frequency, failing to adequately represent the temporal variability in water quality. Therefore, more confidence may be obtained by implementing composite sampling. Moreover, a large portion of the data, gathered according to the water permits, i.e. about the quality of recipient water bodies and discharged wastewater, is not available on the national level.

- The results of nutrient trend analyses are contradictive and no clear correlation between the implemented measures to decrease diffuse and point source load and water quality was detected in many cases. This topic requires future studies. The methodology for source apportionment of nutrients varies a lot in different countries. Therefore, harmonisation is needed to make the results comparable, including for HELCOM reporting.

- The study results indicate that the share of wastewater load in the total load of nutrients to the Baltic Sea is relatively small. Therefore, the potential for further reduction is also restricted. Reduced point source load provides better results with regard to inland surface water bodies, especially during low water periods, but does not give a remarkable effect in reducing the load to the Baltic Sea due to a rather long retention period in Estonian river systems that provides a good basis for self-purification in water bodies.

This aspect requires further investigation. It is very likely that most of the pollution load must be reduced on account of diffuse sources.

- Water quality models are not yet widely used in Estonia. The work done in different institutions is scattered, and there is very little discussion on the use of modelling tools on the national level. This is so also in many other countries. Integrated modelling of the Pärnu River catchment by using the developed linked model system, in order to support water resource management and the decision making process, provided rather good results. However, for verification of the results, another model or model system should be used in parallel.
- As a result of more accurate water metering, the quality of data on water use has improved a lot since the early 1990s. Nevertheless, some data are still missing and there is a need to improve the quality. The structure and data flows of water information subsystems also need further improvement to make all information comparable and available for the decision makers, water authorities, experts and other actors involved in the development of river basin management plans. Statistical data are often presented by administrative units, making it difficult to use the data by the river basin principle.

- The overall organisation of water resources management in Estonia corresponds relatively well to the principles of integrated approach. The use and protection of water resources is regulated by governmental acts in which sustainable water consumption has been established as a goal and an economic value is attached to water. Water management is based on the River District Management Plans compiled for nine river basin sub-districts forming three main river basin districts. The state of aquatic environment is monitored and assessed and data on the pressures and status of water bodies is available via internet for all stakeholders and the public.

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ABSTRACT

The principle of integrated water resources management based on the river basin approach has become increasingly important in the last decades, being recognized as an effective way to improve the quality of water environment. Therefore, one of the major objectives of this doctoral thesis was the assessment of the availability of water resources, water use and current status in Estonia considering the main principles of integrated water resources management and sustainable use. This work includes analyses of nutrient trends in rivers and nutrient load to the recipient water bodies including the Baltic Sea, and developing of scenarios for the reduction of nutrients point source pollution load. Integrated river basin management requires the development of a water resources knowledge base and relevant decision supporting tools that were also tested by the author.

Considering the ratio between water availability and abstraction a conclusion can be made that water resources are in general sufficient in Estonia, although there are some regional variations. Water use has decreased drastically since the 1990s and on the average only 90 litres of water per capita per day were used for human consumption in Estonia in 2008. This level is two times lower than in 1992. A similar decreasing trend is characteristic for wastewater pollution load, driven mainly by socio-economic factors like increased price for water as well as by new technologies, e.g. to diminish losses of water. Most of the Estonian water bodies are assigned to the "good or moderate quality" class. A more precise assessment of the status of water bodies requires additional studies and monitoring data. It includes data collected by water users within their self-monitoring programmes that should be conducted both upstream and downstream of waste-water discharge to the recipient water body and defined by relevant environmental permits.

The assessment of recent trends in nutrient concentrations in Estonian rivers revealed that it is very difficult to draw a direct linkage between the implemented measures to control pollution and nutrient concentrations in rivers. Statistically significant downward or upward trends for nitrogen and phosphorus were usually detected only for relatively smaller rivers but in about 60% of the stations the nutrient concentrations were fairly stable. The Baltic Sea Action Plan provides provisional nutrient load reduction targets for all countries sharing the catchment, including the requirement to decrease the total phosphorus and total nitrogen load from the Estonian territory by 220 and 900 tons, respectively. Our study results and developed scenarios revealed that the capacity for reduction of point source nutrient load to the sea is rather limited. Only about 20% of phosphorus and 25% of nitrogen load directly entering the Baltic Sea could be eliminated when following the most stringent Helcom recommendations for effluents of WWTPs. Knowing that the share of point source nutrient load to the sea is only about 4-5%

of nitrogen and 10-15% of phosphorus, different measures to decrease the diffuse load of nutrients should be implemented.

As an example of the application of a water quality model a Qual2K and the catchment model Wennerblom were linked and applied to simulate the effect of organic matter and nutrients emissions from point and non-point sources on water quality in the Pärnu River Basin. In general the results of the linked model showed quite a large variation in nutrient loads and concentrations from different sub-basins, emphasizing the need to keep a rather detailed structure of land-based pollution models.

Assessment of the existing information systems in Estonia and data requirements shows that data flows are incomplete. Some important links between modules are missing and the agility of the existing information systems is not sufficient to absorb the increasing complexity and heterogeneity of data and information needed for decision making in a fast changing legislative environment. Data availability with regard to non-point sources, drinking and bathing water quality is the most problematic. The necessary new pathways and system parts were therefore described by the author and proposals to amend and join/link all the existing different databases and information systems were developed.

KOKKUVÕTE

Valgala tervikliku korraldamise põhimõte on kujunenud viimastel kümnenditel väga oluliseks, olles tunnistatud tõhusaks viisiks veekogude seisundi parandamisel. Käesoleva doktoritöö oluliseks eesmärgiks oli Eesti veevarude piisavuse, kasutuse ja seisundi hindamine, lähtudes tervikliku haldamise ja säästliku kasutamise põhimõtetest. Töös analüüsiti toitainete suundumust jõgedes ja koormust veekogudele, sealhulgas Läänemerele, koostati ja uuriti erinevaid punktallikatest pärineva reostuskoormuse vähendamise stsenaariume. Valgala terviklik haldamine vajab veevaru kohta käiva teadmiste baasi ja asjakohaste otsuseid toetavate tööriistade arendamist, mis on töö autori poolt ka testitud.

Kasutuseks vaba veevaru ja veekogudest võetava vee hulkade suhe näitab, et Eesti veevarud on üldjuhul piisavad, kuigi piirkonniti on teatud erisused. Alates 1990ndatest on veekasutus Eestis märkimisväärselt langenud. Aastal 2008 oli keskmine veekasutus inimese kohta päevas 90 liitrit, mis on kaks korda vähem kui 1992. aastal. Sama suundumus on iseloomulik ka heitvee reostuskoormusele, põhjuseks sotsiaal-majanduslikud tegurid – veehinna tõus, aga ka rakendatud uued tehnoloogiad, sh veekadude vähendamine. Enamik Eesti veekogudest on määratud heasse või kesisesse veekvaliteediklassi. Vaja on lisauuringuid ja rohkem seireandmeid, et anda täpsemaid hinnanguid veekogude seisundile. See puudutab veekasutajate keskkonnalubades sätestatud omaseire kohustust, mis peaks olema määratud suublaks olevas veekogus ülal- ja allpool heitvee sisse laskmise kohta.

Eesti jõgede toitainete sisalduse suundumuste uurimine ei näidanud otseseid seoseid rakendatud meetmetega. Lämmastiku ja fosfori statistiliselt tähenduslikku tõusu või languse suundumust ilmnes ainult üsna väikese valgalaga jõgedel ja ligikaudu 60% seirejaamades püsis sisaldus üsna stabiilne. Läänemere tegevuskava kohaselt on valgalal olevatele riikidele välja pakutud fosfori ja lämmastiku koormuse vähendamise sihtväärtused, mis Eesti alalt on vastavalt 220 ja 900 tonni. Meie uuringu tulemused ja stsenaariumid näitasid, et heitvee koormuse vähendamise potentsiaal on piiratud. Eestist Läänemerre otselaskmete kaudu juhitud heitvee reostuskoormusest on võimalik eemaldada ainult 20% fosforist ja 25% lämmastikust juhul, kui järgida Helsingi Komisjoni rangeimaid soovitusi heitvee puhastite väljalaskmetele. Teades, et punktallikate reostuskoormus moodustab vaid 4-5% lämmastiku ja 10-15% fosfori kogukoormusest, tuleb rakendada teisi (eri) meetmeid toitainete koormuse vähendamiseks hajuallikates.

Näidisena on välja arendatud integreeritud mudelsüsteem, kuhu on seotud veekvaliteedi mudel Qual2K ja Wennerblomi valgala mudel, mille koostoimel simuleeritakse nii punkt- kui ka hajuallikate orgaanilise aine ja toitainete koormuste mõju Pärnu jõe seisundile. Üldjoontes andsid sellise mudelite sidussüsteemiga saadud tulemused erinevatelt alamvalgaladelt üsna suuri erisusi –

seda nii toitainete koormuse kui ka kontsentratsioonide osas, näidates vajadust säilitada mudelite küllalt detailset struktuuri.

Hinnates Eestis kasutusel olevaid infosüsteeme ja andmevajadusi, tuleb tõdeda, et andmevood ei ole täielikud. Mõned olulised moodulid on puudu ja olemasolevate infosüsteemide võimekus ei ole piisav haaramaks järjest suurenevat keerukat ja erisugust andmehulka ja informatsiooni, mis on vajalik otsuste tegemiseks kiirelt muutuva seadusandluse järgimisel. Näiteks on probleemid suuremad hajuallikate ja joogi- ja suplusvee andmete hankimisel. Olemasolevaid infosüsteeme on autori poolt täiendatud vajalike uute ühenduste ja süsteemi osadega. Samuti on tehtud ettepanekud erinevate andmebaaside ja infosüsteemide sidumiseks, ühendamiseks.

CURRICULUM VITAE

1. Personal data

Name	Karin Pachel
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2. Contact information (at work)

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3. Education

Educational institution	Graduation year	Education
Tallinn University of Technology, Faculty of Civil Engineering	1973 - 1979	Water supply and sewerage engineer
Tallinn 36th Secondary School	1962 - 1973	Graduated

4. Language competence/skills

Language	Level
Estonia	Native language
English	Good
Russian	Fluent

5. Professional Employment

Period	Organisation	Position
2009 - ...	Tallinn University of Technology, Faculty of Civil Engineering, Department of Environmental Engineering, Chair of Water Engineering	Lecturer (1.00)
2007 - 2009	Tallinn University of Technology, Faculty of Civil Engineering, Department of Environmental Engineering, Chair of Environmental Protection	Extraordinary Researcher (0.25)
1992 - 2009	Ministry of Environment, Estonian Environment Information Centre	Water specialist, water chief specialist, Head of Environmental state Bureau, Head of Water Bureau since 2006
1974 - 1992	Land Reclamation Institute	engineer

6. Special Cources

Period	Educational organisation	Description
2002	US EPA Region 5 and Partners	EU Water Framework directive, River Basin Management
1999, three weeks	European Training Foundation and The Phare Multi-Country Programme for Distance Education	European Union's proposed Water Framework Directive and other Water Directives
1998, 1999, two weeks	University of Kuopio, Centre for Training and Development	Environmental monitoring - preparation and evaluation of the monitoring programmes
1998, one month	Uppsala University, Norr Malma Field Station, Vattenresurs AB	Management of Inland, Coastal and Ground Waters with focus on the EU - Water Framework Directive
1993, one month	Freshwater Centre Silkeborg, Denmark	Basic courses on environmental administration and Special course on surface water and waste water

7. Defended theses

Diploma work: Determination of regulative volume of the Soodla II (Anija) reservoir

8. Main areas of scientific work/Current research topics

Water resources and water management, wastewater handling, environmental policy, environmental state assessment, geoinformatics.

9. Main projects

2009-2010, participant of the project Baltic COMPASS: „Comprehensive Policy Actions and Investments in Sustainable Solutions in Agriculture in the Baltic Sea region“ (INTERREG IVA)

2008-2010, participant of the EC Integrated Project Water Scenarios for Europe and for Neighbouring States (SCENES)

2009, 2010, participant of the Life project: „The development of Pay As You Throw Systems in Hellas, Estonia and Cyprus“

2009, 2010, participant of the project: „Development of methods for environmental ecological discharge calculation“. Estonian Environment Ministry

2007, participant of Eurostat and Estonian Statistical Office project „Statistikal inventory of wastewater treatment plants“. Eurostat grant 19100.2005.001-2005.531

2006, participant of Eurostat and Estonian Statistical Office project „Estimation of the wastewater generation by source categories. Eurostat grant 71301.2005.001-2005.017.

2004-2005, participant of the Estonian and Netherland project „Capacity building for the implementation of the Water Framework Directive in Estonia"

2004-2006, participant of Environment Investments Centre project „Elaboration of the web-based infosystem for water use annual reporting and wastewater analysis"

2001-2003, National Programme, Ministry of Environment „Establishing of the ecological classification of the surface water and system control in nature"

1999, 2000, EU integration Project (99/EN/56): The working out the Governmental Regulation: "Regulation establishing quality requirements and usage categories for fresh water bodies"

1999, participant of the GWP project „Mapping and Visioning Project of the interim CEE Technical Advisory Committee of the Global Water Partnership, National Mapping and Vision Report on Water Resources Management, Estonia"

1998, 1999, national coordinator in EEA project: Support to the EUROWATERNET implementation in the Baltic countries. Improve the possibilities to the collection and use of comparable information on freshwater resources and their state for the EEA

1997-1998, Phare project DADAM - Improvement of Data use and Data Management within the Environmental Monitoring Programme

1997,1998, water working group leader of Estonian National Environmental Action Plan, Surface Water and Coastal Water, project of Estonian Environment Ministry

1996, 1997, participant of Baltic Environmental Forum project „Baltic State of the Environment Report based on environmental indicators", Water resources (incl. groundwater) and Eutrophication, indicators

1996-1997, Finnish-Estonian-Russian project „Pollution load of the Gulf of Finland" (The Year of the Gulf of Finland)

ELULOOKIRJELDUS

1. Isikuandmed

Nimi	Karin Pachel
Sünniaeg ja -koht	18.06.1955, Tallinn
Kodakondsus	Eesti

2. Kontaktandmed (tööl)

Aadress	Ehitajate tee 5, Tallinn, 19086
Telefon	+3726202511
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3. Hariduskäik

Õppeasutus	Lõpetamise aeg	Haridus
Tallinna Tehnikaülikool, Ehitusteaduskond	1973 - 1979	Veevarustuse ia kanalisatsiooni insener
Tallinna 36. Keskkool	1962 - 1973	Keskharidus

4. Keelteoskus

Keel	Tase
Estonia	Emakeel
English	Hea
Russian	Väga hea

5. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2009 - ...	Tallinna Tehnikaülikool, Ehitusteaduskond, Keskkonna-tehnika Instituut, Veetehnika õppetool	Lektor (1.00)
2007 - 2009	Tallinna Tehnikaülikool, Ehitusteaduskond, Keskkonna-tehnika Instituut, Keskkonnakaitse aluste õppetool	Erakorraline teadur (0.25)
1992 - 2009	Keskkonnaministeeriumi Info-ja Tehnokeskus	Veespetsialist, Keskkonnaseisundi büroo juhataja, Veebüroo juhataja alates 2006
1974 - 1992	Eesti Maaparandusprojekt	insener

6. Täiendusõpe

Õppimise aeg	Läbiviija nimetus	Märkused
2002	US EPA Region 5 and Partners	Euroopa Liidu Veepoliitika raamdirektiiv, Valgala veemajanduskavade koolitusprogramm
1999, kolm nädalat	Euroopa Keskkonnagentuuri ja Phare koolitusprogramm, Budapesti Põllumajandusülikool	Euroopa Liidu veealaste seadusanluse ja Vee Raamdirektiivi ülesehitus, nõuded ja rakendumine
1998, 1999	Kuopio Ülikool	Keskkonnaseire programmide ettevalmistamine ja rakendamine
1998, üks kuu	Uppsala Ülikool, Norr Malma Välijaam, Vattenresurs AB	Siseveekogude, rannikumere ja põhjavee olukord ja seadusandlus Euroopa Liidu veedirektiivide ja EL Vee Raamdirektiivist lähtuvalt
1993, üks kuu	Taani Silkebori Veekeskus	Keskkonnakorralduse põhikursus ja pinna- ja heitvee erikursus

7. Kaitstud lõputööd

Diplomitöö: „Soodla II (Anija) veehoidla optimaalse reguleeriva mahu määramine“

8. Teadustöö põhisuunad

Veevaru ja veemajandus, heitvee käitlus, keskkonnaalane õigusloome, keskkonna seisundi hindamine

9. Peamised projektid

2009-2012, osaleja projektis Baltic COMPASS: „Poliitika ja investeeringud jätku-suutlikeks lahendusteks Läänemere regiooni põllumajandustootmises“ (INTERREG IVA)

2008-2010, osaleja EL VI Raamprogrammi projektis SCENES „Pikaajalised muutused vee kvaliteedis ja kvantiteedis Euroopas ning tulevikustsenaariumid“

2009, 2010, osaleja Life projektis: „Täpsema jäätmete maksustamise süsteemi väljaarendamine Kreekas, Eestis ja Küprosel“

2009, 2010, osaleja Keskkonnaministeeriumi projektis; „Ökoloogilise miinimum-vooluhulga arvutusmetoodika väljatöötamine“

2007, osaleja Euroopa ja Eesti Statistikaametite projektis „Heitveepuhastite statistiline inventuur“. Eurostat grant 19100.2005.001-2005.531

2006, osaleja Euroopa ja Eesti Statistikaametite projektis "Heitvee tekke hindamine majandustegevusalade järgi". Eurostat grant 71301.2005.001-2005.017

2004-2005, osaleja Eesti ja Hollandi koostööprojektis „Capacity building for the implementation of the Water Framework Directive in Estonia"

2004-2006, osaleja Keskkonnainvesteeringute keskuse projektis „Veekasutuse ja heitvee analüüside veebipõhise infosüsteemi loomine"

2001-2003, Rahvuslik programm. Eesti keskkonnaministeerium „Pinnaveekogude ökoloogilise klassifikatsiooni välja töötamine ja testimine"

1999, 2000, EL integratsiooni projekt (99/EN/56): Veekvaliteedi näitajatele tuginevate veekoguklasside keskkonnaministri määruse eelnõu koostamine (jõgede ja järvede osa)

1999, osaleja GWP projektis „Visioon Kesk- ja Ida-Euroopa riikide veepoliitika olevikust, tulevikust ning tegevusraamistik, Eesti osa"

1998, 1999, rahvuslik ekspert Euroopa Keskkonnaagentuuri ja Soome Keskkonnainstituudi projektis: „Euroopa Keskkonnaagentuuri seire- ja informatsioonivõrku koondatavate andmete valik ja töötlus"

1997-1998, osaleja Phare projektis DADAM: „Keskkonnaseire programmide järgi kogutud andmete korraldamise, töötlemise ja kasutamise tõhustamine"

1997,1998, vee töögrupi juht Keskkonnaministeeriumi projektis: „Eesti riiklik keskkonnategevuskava pinna- ja rannikumere osas"

1996, 1997, osaleja Balti Keskkonnafoorumi projektis: „Balti riikide keskkonna seisund keskkonnaindikaatorite järgi", Veevarud ja eutrofeerumine

1996-1997, Soome-Eesti-Venemaa ühisprojekt „Soome lahe reostuskoormus" (Soome lahe aasta)

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Piirimäe, K., **Pachel, K**., Reihan, A., 2010. Adaptation of a method for involving environmental aspects in spatial planning of river basin management – a case study of the Narva River catchment. Approved in Estonian Journal of Ecology.

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Lips, U., Loigu, E., Lääne, A., Martin, G., **Pachel, K**., Raia, T.,1998. Soome lahe seisund ja tulevik. Tallinn: Keskkonnaministeerium.

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Pachel, K., 1993. Jõed ja nende seisund - Eesti jõgede ja järvede seisund. Water Pollution and Quality in Estonia in Environmental Report 7, 1993, Environment Data Centre (EDC), National Board of Waters and Environment, Finland, 5–10.

Pachel, H., **Truu, K.**, 1986. Reoaine lubatud piirhulgad eesvoolus, Eesti Maaparandusprojekt. 1986, pp 117.

Pachel, H., **Truu, K.,** Sild, H., 1985. Eesti NSV jõgede arvutuslik veekvaliteet, Eesti Maaparandusprojekt, 1985, pp 207.

Pachel, H., Suuressaar, L., **Truu, K**., 1984. Eesti NSV veekogude kasutuskategooriad ja lubatud reostuskoormused. Eesti NSV jõgede kasutuskategooriad. Eesti Maaparandusprojekt, 1984, pp 100.

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Pachel, K., 2002. Estonian national report on nutrient loads. In: Evaluation of the implementation of the 1988 Ministerial Declaration regarding nutrient load reductions in the Baltic Sea catchment area. Finnish Environment 524, International cooperation, Finnish Environment Institute, 90-102.

PAPER II

Paper II: Stålnacke, P., Sults, Ü., Vassiljev, A., Skakalsky, B., Botina, A., Roll, G., **Pachel, K.**, Maltsman, T., 2002. An assessment of riverine loads of nutrients to Lake Peipsi, 1995-1998. Archiv für Hydrobiologie. Supplementband. Large rivers 141, 437-457.

Paper III

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Paper IV

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Paper V

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Paper VI

Iital, A., **Pachel, K**., Loigu, E., Pihlak, M., Leisk, Ü., 2010. Recent trends in nutrient concentrations in Estonian rivers as a response to large-scale changes in land-use intensity and life-styles. Journal of Environmental Monitoring, 2010, 12, 178–188.

DISSERTATIONS DEFENDED AT TALLINN UNIVERSITY OF TECHNOLOGY ON *CIVIL ENGINEERING*

1. **Heino Mölder**. Cycle of investigations to improve the efficiency and reliability of activated sludge process in sewage treatment plants. 1992.

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11. **Targo Kalamees**. Hygrothermal criteria for design and simulation of buildings. 2006.

12. **Raido Puust**. Probabilistic leak detection in pipe networks using the SCEM-UA algorithm. 2007.

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16. **Ira Didenkulova**. Long wave dynamics in the coastal zone. 2008.

17. **Alvar Toode**. DHW consumption, consumption profiles and their influence on dimensioning of a district heating network. 2008.

18. **Annely Kuu**. Biological diversity of agricultural soils in Estonia. 2008.

19. **Andres Tolli**. Hiina konteinerveod läbi Eesti Venemaale ja Hiinasse tagasisaadetavate tühjade konteinerite arvu vähendamise võimalused. 2008.

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23. **Loreta Kelpšaitė**. Changing properties of wind waves and vessel wakes on the eastern coast of the Baltic Sea. 2009.

24. **Dmitry Kurennoy.** Analysis of the properties of fast ferry wakes in the context of coastal management. 2009.

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