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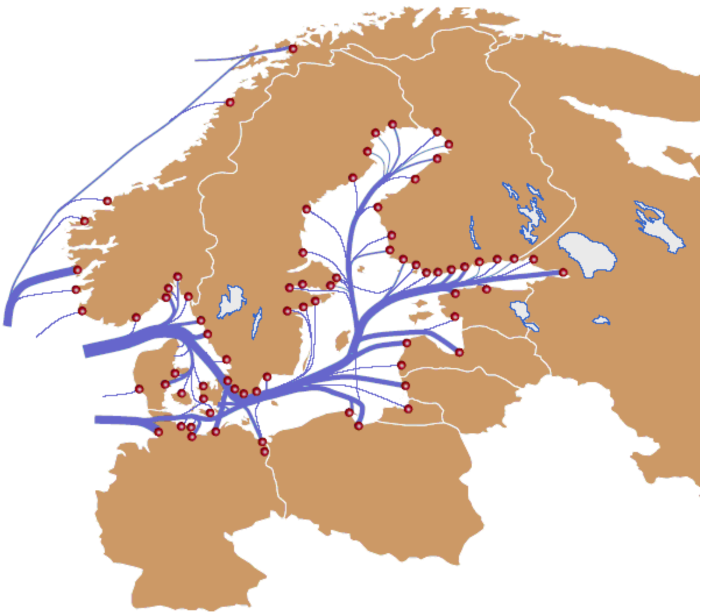

Estimated nutrient load from waste waters originating from ships in the Baltic Sea area – Updated 2009

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Summary

This report is an update of VTT's Research Notes 2370 "Estimated nutrient load from waste waters originating from ships in the Baltic Sea area". On the basis of the calculations and references, the nutrient load originating from ships is rather small, but not negligible due to the sensitivity of the Baltic Sea marine environment. The ship-borne nitrogen load represents approximately 0.04% of the total nitrogen load, and the phosphorus load represents approximately 0.3% of the total phosphorus load both into the Baltic Sea area and into the Gulf of Finland. The main nutrient load into the Baltic Sea is derived from water-borne inputs and atmospheric deposition. The nutrient load from ships is much easier to reduce, when compared to the atmospheric emissions or nutrient inputs from land-based sources, by requiring ships to discharge the sewage into the sewer network ashore or by installing waste-water purification systems on-board. In the future, it is likely that limits will be set for the concentration of nitrogen and phosphorus in ships' waste waters.

The purpose of this updated study was to provide background information for the *ad hoc* HELCOM Correspondence Group regarding the possible designation of the Baltic Sea as a special area where more stringent regulations on discharges of sewage from ships would be applied. The main task of the Group is to estimate the effect of the new proposals for new provisions in MARPOL Annex IV on the nutrient load of the Baltic Sea.

The new information presented in this report was gathered by the authors and the members of the *ad hoc* HELCOM Correspondence Group. The information was mainly obtained from the manufacturers of the on-board waste-water treatment systems. Also the Cruise Lines International Association and the European Cruise Council provided information concerning the utilization of the port reception facilities in the Baltic Sea area and nutrient load estimations. The intention was to determine the current situation of the waste-water reception facilities and their usage in the Baltic ports. Also, the availability and estimated costs of on-board sewage treatment plants capable of reducing discharges of nitrogen and phosphorus were investigated.

Confidentiality	Public

Espoo 20.3.2009

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Preface (updated)

Since the 1800s, the Baltic Sea has changed from being an oligotrophic clear-water sea into a eutrophic marine environment. The Baltic Sea is one of the world's largest brackish water areas and is ecologically unique. It is highly sensitive to the environmental impacts resulting from human activities in its catchment area. Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae, which leads to an imbalance in the functioning of the system: intense algal growth means an excess of filamentous algae and phytoplankton blooms, the production of excess organic matter, an increase in oxygen consumption, oxygen depletion and the death of benthic organisms, including fish.

Maritime transport in the Baltic Sea area, and especially in the Gulf of Finland, has changed significantly over the last decade. The new oil terminals in Russia and the economic boom in the Baltic States have resulted in a remarkable rise in maritime traffic, mainly tankers and cargo ships. Meanwhile, the customers' environmental awareness has become an important image and competition factor among the shipowners and ports.

This report is an update of VTT's Research Notes 2370 "Estimated nutrient load from waste waters originating from ships in the Baltic Sea area", which was published in 2007. The purpose of the original study was to estimate the nutrient load from waste waters originating from ships in the Baltic Sea area. The study also included information about the maritime traffic, waste-water management and legislation. The estimated nutrient load from ship-generated sewage was calculated, assuming there is no waste-water treatment on-board and all waste waters are discharged into the sea.

On the basis of the calculations and references, the nutrient load originating from ships is rather small, but not negligible due to the sensitivity of the Baltic Sea marine environment. The nutrient load is concentrated along the shipping routes and is immediately available for uptake by, e.g., blue–green algae, adding to the severe eutrophication of the Baltic Sea.

The vulnerable nature of the Baltic Sea area and the ever-increasing eutrophication are forcing a reduction in the nutrient load into the Baltic Sea. The nutrient load from ships is much easier to control, when compared with the atmospheric emissions or nutrient inputs from land-based sources even though the main nutrient load is derived from the latter.

The purpose of this updated study was to provide background information for the *ad hoc* HELCOM Correspondence Group regarding the possible designation of the Baltic Sea as a special area where more stringent regulations on discharges of sewage from ships would be applied. The main task of the Group is to estimate the effect of the new proposals for new provisions in MARPOL Annex IV on the nutrient load of the Baltic Sea.

This report was commissioned by the Finnish Maritime Administration.

Espoo, 20.3.2009

Authors

Contents

1 Introduction (updated)

Since the 1800s, the Baltic Sea has changed from being an oligotrophic clear-water sea into a eutrophic marine environment. The Baltic Sea is one of the world's largest brackish water areas and is ecologically unique. It is highly sensitive to the environmental impacts resulting from human activities in its catchment area. In recent years the Baltic Sea has suffered from excessive eutrophication caused by the long-lasting airborne and water-borne nutrient loads. Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae, which leads to an imbalance in the functioning of the system: intense algal growth means an excess of filamentous algae and phytoplankton blooms, the production of excess organic matter, an increase in oxygen consumption, oxygen depletion and the death of benthic organisms, including fish.

The nutrient load has been restricted by setting limits on the discharges from sewage disposal plants. So far, the attempts to diminish the nutrient load into the Baltic Sea have been inadequate, e.g. the blue-green algal blooms are still occurring every summer. Restriction of the external nutrient load is extremely important because all the incoming nutrients only worsen the eutrophication of the Baltic Sea".

One source of the water-borne nutrient load is maritime traffic. According to the MARPOL regulations 73/78 Annex IV, the discharge of sewage into the sea is allowed if the ship is discharging comminuted and disinfected sewage using a system approved by the Administration at a distance of more than 3 nautical miles from the nearest land, or sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land, provided that, in any case, the sewage that has been stored in holding tanks shall not be discharged instantaneously but at a moderate rate when the ship is en route and proceeding at not less than 4 knots. If the ship has in operation an approved sewage treatment plant which has been certified by the Administration, discharge of sewage is permitted anywhere. The effluent shall not produce visible floating solids nor cause discoloration of the surrounding water. The public disapproval that arose in Finland after it became known that some shipping companies discharge sewage into the Baltic Sea has particularly affected the passenger ship companies, and most of the passenger ship companies have started to discharge the sewage into the municipal sewer network ashore.

Finland has regarded the above-mentioned MARPOL 73/78 Convention as inadequate in relation to the Baltic Sea's sensitive marine environment. In 2006, Finland made a suggestion at HELCOM for defining the amount of nutrient load originating from ship sewage in the Baltic Sea area. The VTT Technical Research Centre of Finland was commissioned to conduct a study of the nutrient load from maritime traffic discharged into the Baltic Sea. As part of this study, questionnaires on the waste water and passenger amounts were sent to the ports and shipowners in the Baltic Sea area.

Thus, the purpose of the original study was to estimate the nutrient load from waste waters originating from ships in the Baltic Sea area. On the basis of the calculations and references, the nutrient load originating from ships is rather small, but not negligible due to the sensitivity of the Baltic Sea marine environment. The nutrient load is concentrated along the shipping routes and is immediately available for uptake by, e.g., blue–green algae, adding to the severe eutrophication of the Baltic Sea.

The vulnerable nature of the Baltic Sea area and the ever-increasing eutrophication is forcing a reduction in the nutrient load into the Baltic Sea. The nutrient load from ships is much easier to control, when compared with the atmospheric emissions or nutrient inputs from diffused land-based sources. Due to the ‘no special fee’ system, the Baltic Sea ports have invested in waste reception facilities.

The purpose of this updated study was to provide background information for the *ad hoc* HELCOM Correspondence Group regarding the possible designation of the Baltic Sea as a special area where more stringent regulations on discharges of sewage from ships would be applied. The main task of the Group is to estimate the effect of the new proposals for new provisions in MARPOL Annex IV on the nutrient load of the Baltic Sea. The new information in this report is gathered by the authors and the members of the *ad hoc* HELCOM Correspondence Group and it consists of:

- Availability of sewage treatment plants capable of reducing discharges of nutrients (nitrogen and phosphorus).
- Voluntary discharge of sewage into port reception facilities (PRFs) in the ports of the Baltic States (the amount of sewage discharged into PRFs).
- Technical problems related to the discharge of sewage into PRFs.
- Update of the estimate of the environmental consequences of discharge of sewage into the Baltic Sea
- Other relevant information on the issue.

A rather wide inquiry was sent to the manufacturers of sewage treatment plants but unfortunately only a few responses were received. The *ad hoc* HELCOM Correspondence Group had a slightly better response rate from the ports. In addition, a response was received from the Cruise Lines International Association (CLIA), Inc. The Cruise Line International Association represents 24 member cruise lines that operate approximately 175 passenger vessels under various international flags. Also, the European Cruise Council (ECC) provided responses concerning nutrient load estimations and PRFs.

Chapters 5 and 6 have been added to this report, and the Preface, References and Chapters 1, 7, 8, 10 and 11 have been updated. The remaining chapters have been preserved in their original form.

2 Nutrient load sources and inputs in the Baltic Sea area

2.1 General

This study covers the Baltic Sea area. For the purposes of the Helsinki Convention and MARPOL 73/78, the Baltic Sea area is defined as the Baltic Sea Proper, with the Gulf of Bothnia, the Gulf of Finland and the entrance to the Baltic Sea bounded by the parallel of the Skaw in the Skagerrak at 57 degrees 44.8 minutes North. The Baltic Sea area does not include the internal waters of the Coastal States (HELCOM, 1992a). The catchment area of the Baltic Sea is ca. four times larger than the sea area itself and serves as home to some 85 million people. The Baltic Sea catchment area is presented in Figure 2-1.

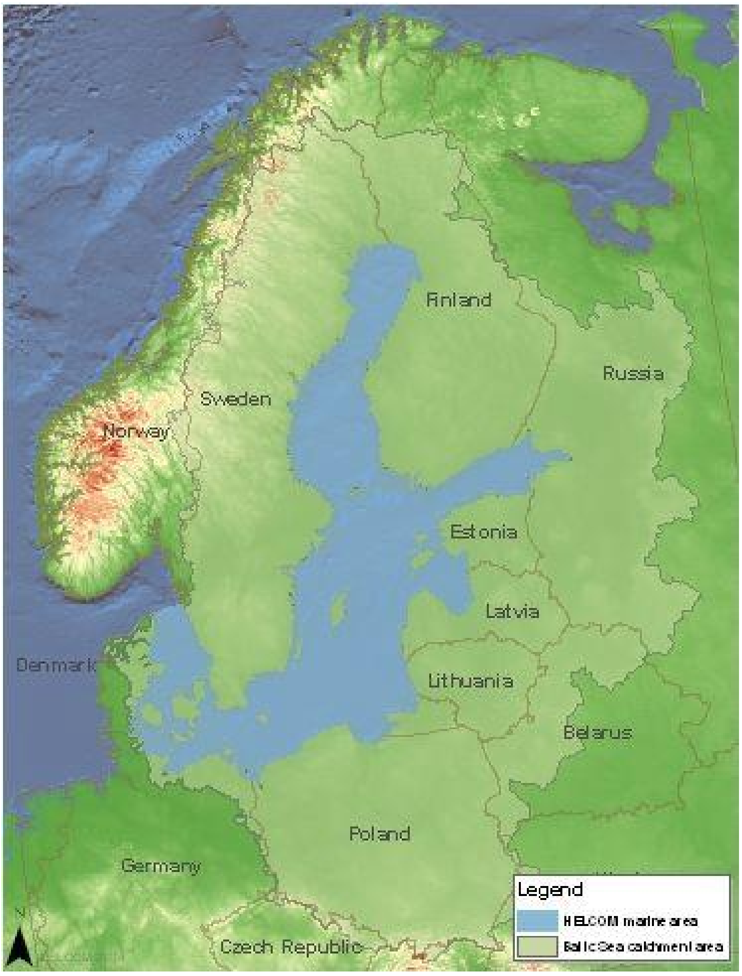

Figure 2-1. The Baltic Sea catchment area (HELCOM, 2005).

The Baltic Marine Environment Protection Commission (HELCOM) describes the nature of Baltic Sea in the following way: “The Baltic Sea is connected to the North Sea by the narrow and shallow waters of the Sound and the Belt Sea. This limits the exchange of water with the North Sea, and means that the same water remains in the Baltic for up to 30 years – along with all the organic and inorganic matter it contains. The average depth of Baltic Sea is only 53 metres. It contains 21,547 km³ of water and every year rivers bring about 2% of this volume of water into the sea as runoff” (HELCOM, 2006).

The Baltic Sea is the largest area of brackish water in the world. Due to the slow rate of natural cleansing and the low salinity level, the Baltic Sea marine ecosystem is very vulnerable to pollution. Only relatively few animal and plant species live in the brackish ecosystems of the Baltic Sea. Some marine and freshwater species are adapted to the brackish conditions, and there are also a few true brackish water species living the Baltic Sea. The Baltic Sea's special geographical, climatological and oceanographic characteristics make it highly sensitive to the environmental impacts of human activities in its catchment area. Therefore, several protected areas have been established in the Baltic Sea area. These areas include Baltic Sea Protected Areas (BSPAs), the Convention on Wetlands of International Importance (COWI or Ramsar Convention), UNESCO's Biosphere reserve areas and the EU's Bird Directive areas. The Baltic Sea area is also one of the IMO's particularly sensitive sea areas (PSSA). The protected areas are presented in Figure 2-2 (HELCOM, 2006; Hänninen & Rytkönen, 2004).

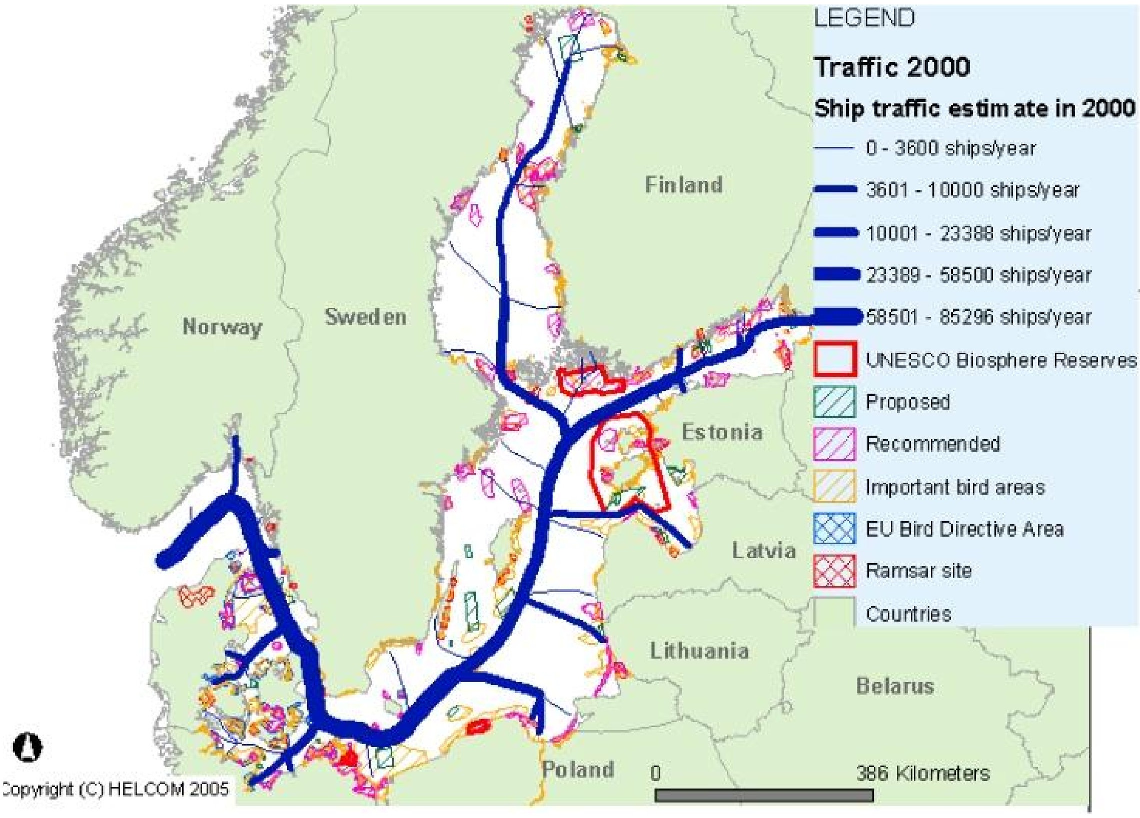

Figure 2-2. Baltic Sea protected areas.

Nowadays, the oxygen-depleted areas are unusually wide in the Baltic Sea. Due to the slow water exchange, excessive external nutrient input and the internal nutrient loading, intense blue-green algal blooms are a common phenomenon in the summertime. The Baltic Sea is also strongly affected by hazardous substances, increased maritime transport and fisheries. The major part of the pollution originates as water-borne from land-based sources. Other sources of pollution are atmospheric deposition and maritime traffic (BMEPC, 1990; Hänninen & Rytkönen, 2004).

The ship-based pollution is released either accidentally or deliberately. Oil and chemical spillages can create severe acute problems for the marine life. Chemical spillages can also cause danger to human health. Sewage discharges from ships disappear quicker from the water surface, but they are no less harmful than oil and chemical discharges. Human sewage can carry enteric bacteria, pathogens, diseases, viruses, the eggs of intestinal parasites and harmful nutrients. Grey water also contains pollutants such as faecal coliform, food waste, detergents, oil, grease, shampoos, cleaners, pesticides and heavy metals. Ingesting contaminated fish or direct exposure to water contaminated with sewage pose health risks for humans. Discharges of untreated or inadequately treated waste water from ships can cause bacterial and viral contamination of commercial and recreational shellfish beds, producing serious risks to public health (The Ocean Conservancy, 2002).

The eutrofying plant nutrients nitrogen and phosphorus are a significant part of the waste water. The quantity of nitrogen in the sewage water is 12–15 g/person/day. The quantity of phosphorus in the sewage water is remarkably lower than the quantity of nitrogen. Nowadays, the usual amount of phosphorus is between 3–5 g/person/day (RIL, 2003).

Nitrogen and phosphorus are among the main growth-limiting nutrients in aquatic ecosystems, and, as such, do not pose any direct hazards for the marine organisms. Eutrophication, however, is a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae, which leads to an imbalanced functioning of the system (RIL, 2003):

- intense algal growth: excess of filamentous algae and phytoplankton blooms
- production of excess organic matter
- increase in oxygen consumption
- oxygen depletion
- death of benthic organisms, including fish.

2.2 Pathways, sources and amounts of nutrient input

The main pathways of the nutrient input are the following (HELCOM, 2005):

- Direct atmospheric deposition on the sea surface.
- River inputs to the sea. Rivers transport nutrients that have been discharged or leached to inland surface waters within the Baltic Sea catchment area.
- Point sources discharging direct to the sea.

Nitrogen enters the Baltic Sea either as airborne or water-borne inputs; phosphorus mainly as water-borne.

The different sources for the inputs of nitrogen and phosphorus are shown in Figure 2-3:

- Atmospheric emissions of nitrogen compounds from traffic or combustion of fossil fuels (heat generation), and from animal manure and husbandry, etc.
- Point sources, including inputs from municipalities, industries and fish farms, both discharging into inland surface waters and directly into the Baltic Sea.
- Diffuse sources, which mainly originate from agriculture but also include nutrient losses from, e.g., managed forestry and scattered dwellings.
- Natural background sources, mainly referring to natural erosion and leakage from unmanaged areas, and the corresponding nutrient losses from, e.g., agricultural and managed forested land that would occur regardless of human activities.

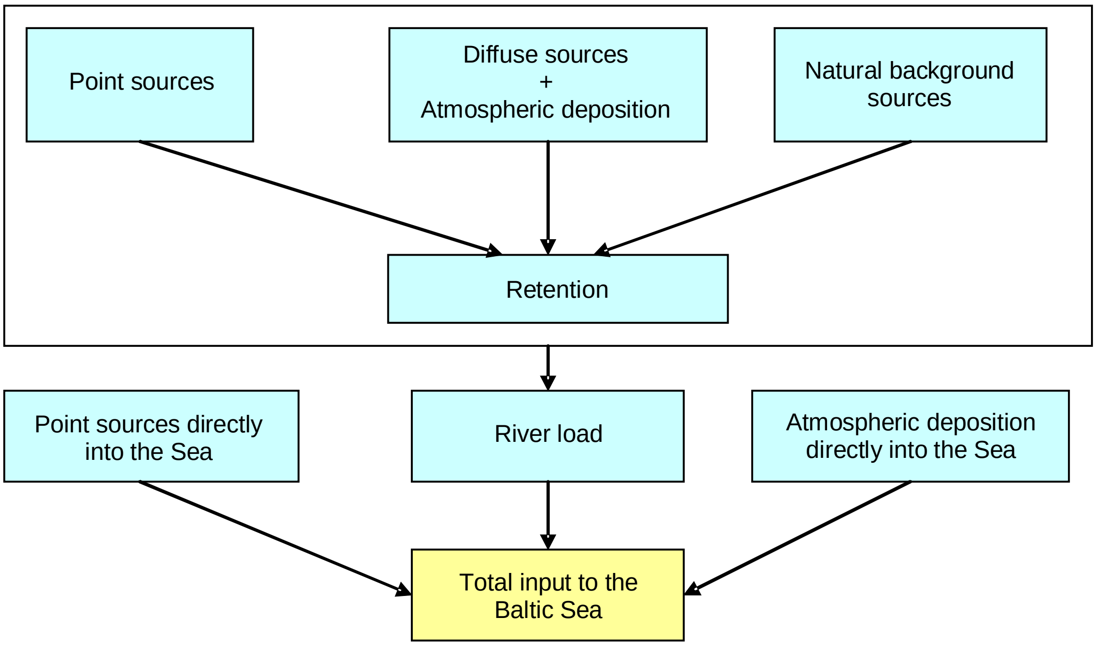

Figure 2-3. Sources of nutrients within the Baltic Sea catchment area (HELCOM, 2005).

In 2000 the atmospheric deposition of nitrogen amounted to 264,100 tonnes, and the total water-borne input of nitrogen was 744,900 tonnes. Thus the total input of nitrogen into the Baltic Sea was 1,009,000 tonnes (HELCOM, 2005).

The inputs of airborne nitrogen have decreased recently. In 2003 the atmospheric supply of nitrogen was 217,000 tonnes. In 2004 the total water-borne load of nitrogen entering the Baltic Sea amounted to 502,000 tonnes. No data was submitted from Russia and Latvia for 2004 (Knuuttila, 2005).

About 75% of the nitrogen entered the Baltic Sea as water-borne input and 25% as airborne input. Diffuse loading, mainly from agriculture and managed forestry, contributed almost 60% of the water-borne inputs to the sea, 28% entered from the natural background sources and 12% came from point sources.

Phosphorus mainly enters the Baltic Sea as water-borne input, but it can also enter as atmospheric deposition. However, it has been estimated that the airborne contribution is only 1–5% of the total phosphorus input. The total phosphorus input was 34,500 tonnes in 2000. In 2004 the total phosphorus load was 22,500 tonnes, but no data was submitted by Russia and Latvia.

Concerning the phosphorus input, diffuse loading contributed nearly 50% of the total water-borne phosphorus inputs to the sea. Point sources and natural background sources each contributed approximately 25% of the phosphorus input (HELCOM, 2005).

The proportion of sources contributing to phosphorus inputs into the Baltic Sea sub-regions in 2000 is presented in Figure 2-4.

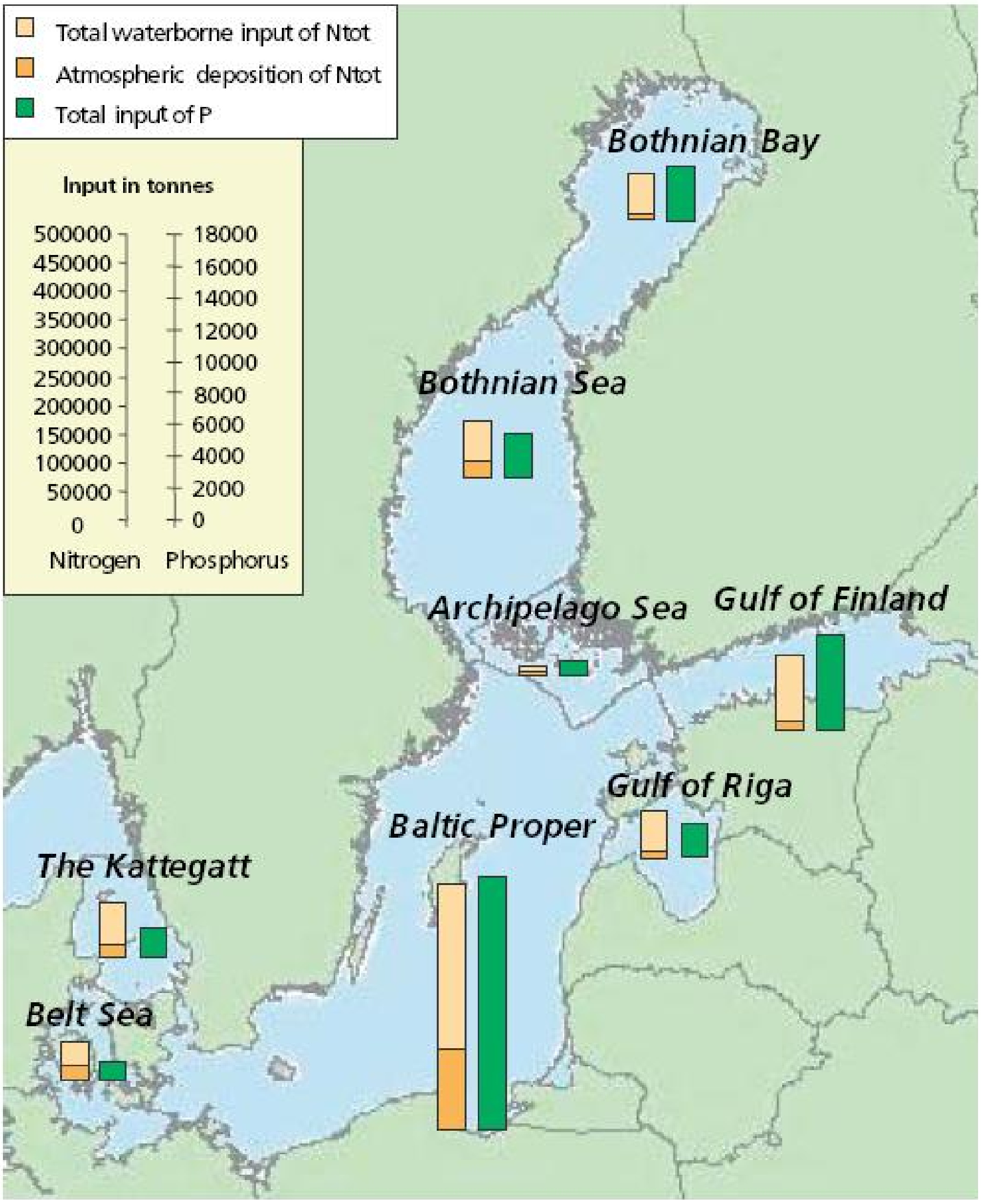

Figure 2-4. Proportion of sources contributing to phosphorus inputs into Baltic Sea sub-regions in 2000 (HELCOM, 2005).

A large proportion of the nutrient loads originate far away from the sea, and even from outside the HELCOM area. Many processes occur after nutrient input into the catchment area, which affect their final input to the Baltic Sea. Rainfall and subsequent river run-off, as well as groundwater inflow to inland surface waters, are controlling factors that determine the final amounts of nutrients entering the Baltic Sea. Biological, physical, morphological and chemical factors also retain and/or transform nutrients within river systems.

Another cause of increased nutrient levels in the sea, especially in the case of phosphorus, is the "internal load": phosphorus reserves accumulating in the sediments on the sea bed are released back to the water under anoxic conditions (HELCOM, 2005).

High nitrate concentrations are still prevalent in the Bothnian Bay, the Gulf of Finland, the Gulf of Riga, the Pomeranian Bay, the Belt Sea and the Kattegat (Figure 2-5). Concentrations of both nitrogen and phosphorus have increased in deep waters (HELCOM, 2006).

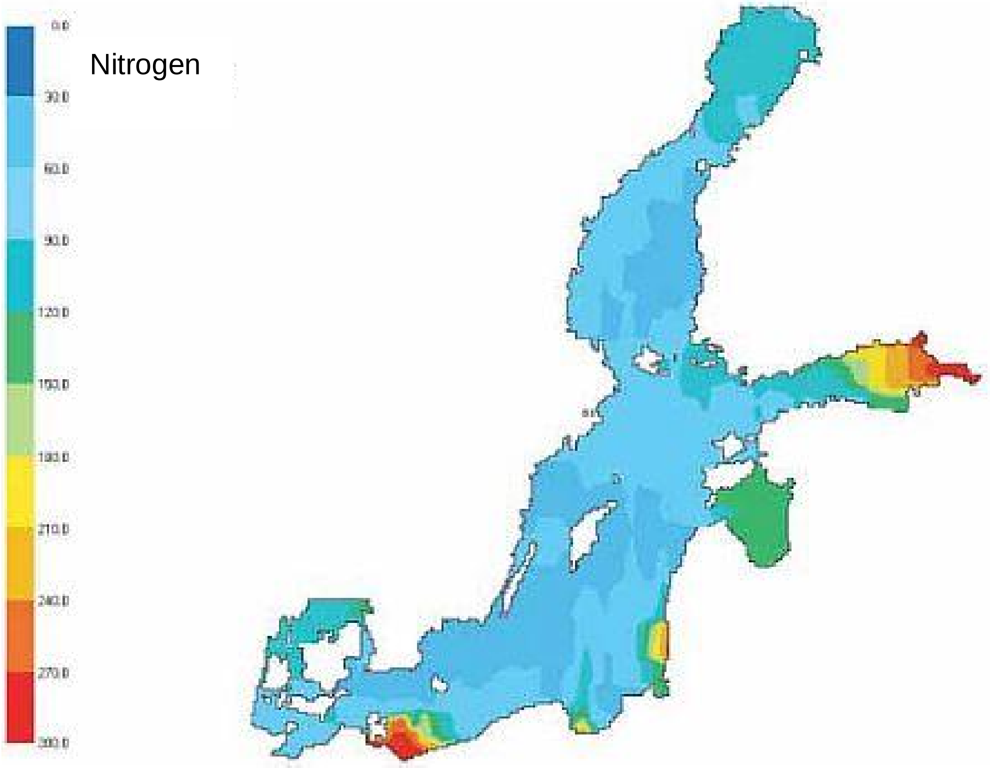

Figure 2-5. Regional distribution of nitrate nitrogen (µg/l) in the surface water, January–February 2000 (HELCOM, 2006).

In general, nutrient concentrations in the Baltic Sea have not decreased since the assessment period 1994–1998; instead, they have increased or remained persistently high. But, from a longer-term perspective, different trends can be seen. Winter surface concentrations of dissolved inorganic nitrogen compounds (nitrate + nitrite) have decreased significantly since 1980, but only in the northern Baltic Proper (HELCOM, 2006).

3 Maritime traffic in the Baltic Sea area

Traffic data was requested from harbours and ship-owners that operate in the Baltic Sea area. All the major harbours were contacted directly or via national port associations (Appendix 1). The following information was requested from each port (Appendix 2):

- number of passengers annually (latest available data)
- number of ship calls annually, divided in different ship types (passenger ships, oil tankers, bulk carriers, etc.)
- amount of received waste waters (black water and grey water separated)
- reception facilities for waste waters.

In addition to the Finnish ports, 9 ports from Estonia and Russia, 4 ports from Latvia, 3 ports from Poland, 2 ports from Lithuania, 20 ports from Denmark, 7 ports from Germany and 38 ports from Sweden were contacted and asked for the same information. A total of 29 answers were received, which means that only approximately 26% of the ports replied to the inquiry. The answers were received from ten cargo ports and 19 passenger ports. A summary of the responses is presented in Appendices 5 and 6.

In most of the ports the amount of received waste water compared to the number of ship calls was considerably smaller, as can be seen in Figure 3-1. The cargo ports had not received sewage in 2005 and only the biggest passenger ports had received waste water.

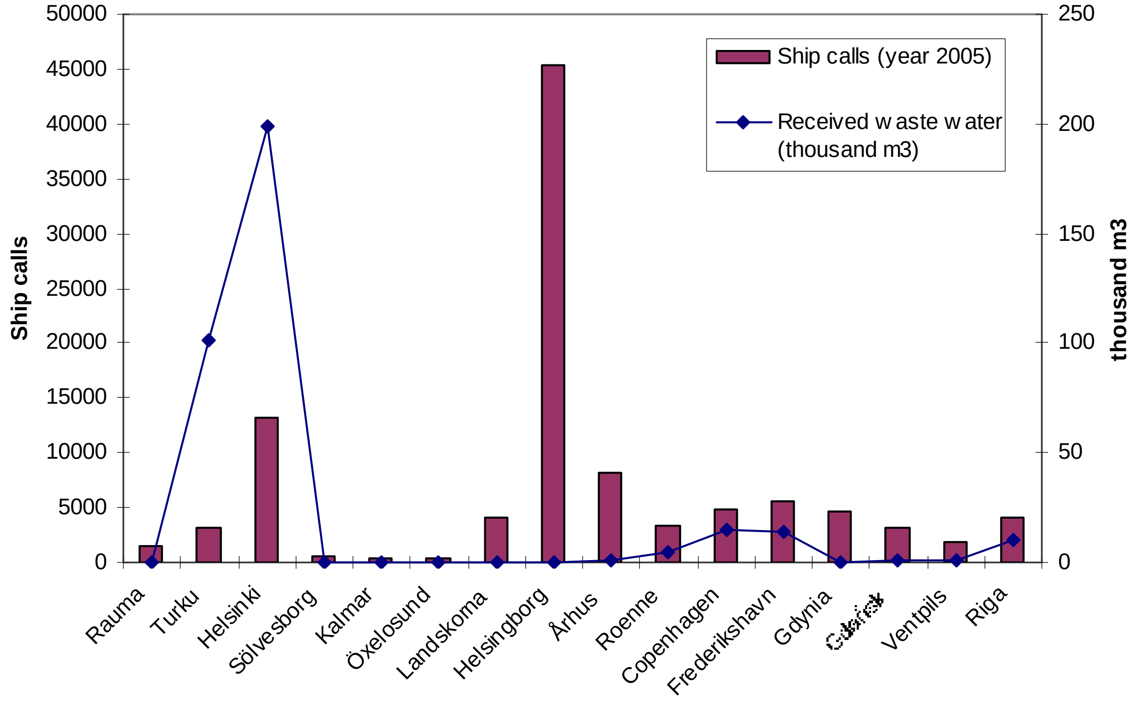

Figure 3-1. Received waste water and ship calls in 2005.

In most of the cargo and passenger ports the waste water from the ship is pumped to a tank truck. In some of the Finnish and Swedish passenger ports the sewage can be discharged directly into the sewer network. Of the 29 ports that replied, three Swedish ports announced that they do not have waste-water reception facilities.

The ship-owners (Appendix 3) received the inquiry (Appendix 4) with the following questions:

– total number of passengers annually (2005) for different routes in the Baltic Sea area
– amount of waste waters (both black and grey) per person per journey
– average time for one journey (if you operate several routes, average time for each route)
– type of waste-water treatment technology for black and grey waste waters utilized onboard your ships.

The inquiry was sent to 16 shipping companies in Finland. Because the contact information for foreign shipping companies was not known, the inquiry was sent to the shipowners' associations in Sweden, Denmark and Germany, and the port authorities in Russia, Estonia, Latvia, Lithuania and Poland. The port authorities and shipowners' associations were asked to forward the questionnaires to the shipping companies. The number of replies was quite low. The information was received from three shipping companies in Finland and three shipping companies in Denmark. No answers were received from companies that transport cargo. A summary of the responses is presented in Appendix 7.

The relationship between the travel time and waste-water production on the basis of the inquiry is presented in Figure 3-2. The amount of sewage per passenger increases as the duration of the journey becomes longer. However the waste-water production is not directly proportional to the travel time.

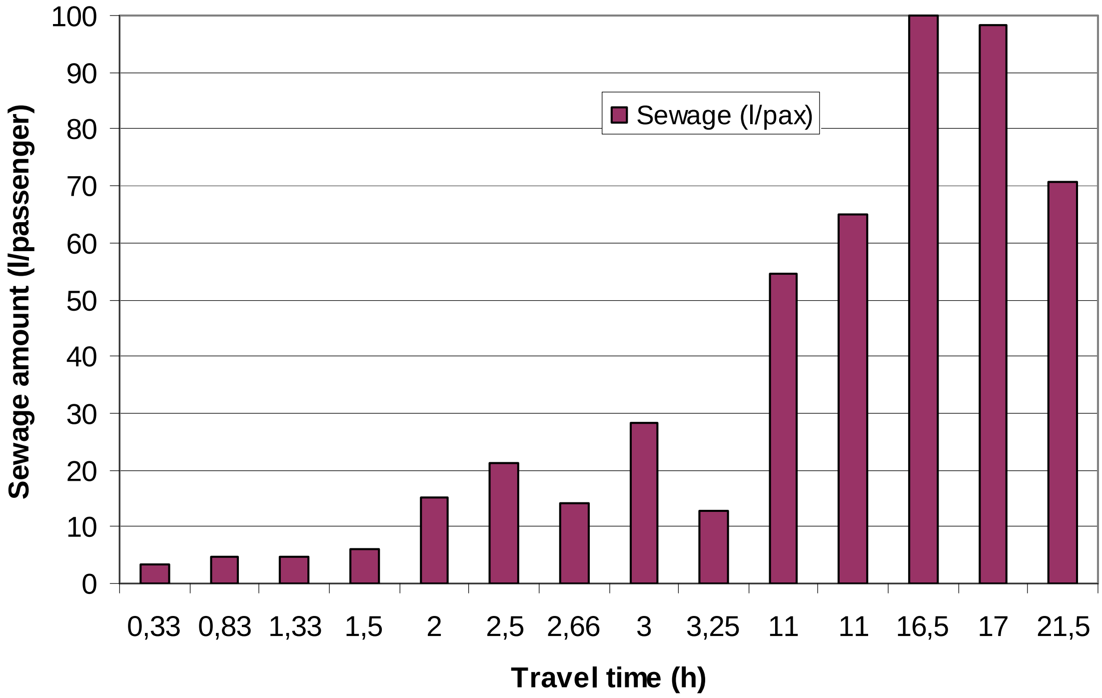

Figure 3-2. Waste-water production vs. travel time.

The sewage production increases considerably when the travel time exceeds ten hours. This is due to the fact that there are passenger services, e.g. day spas and hairdressers, on the longer routes that increase the water consumption and hence the amount of waste water.

The MARPOL 73/78 Convention demands that every ship shall be equipped with one of the following systems:

- a sewage treatment plant
- a sewage comminuting and disinfecting system for the temporary storage of sewage when the ship is less than three nautical miles from the nearest land
- a holding tank of sufficient capacity for the retention of all sewage, having regard to the operation of the ship, the number of persons on-board and other relevant factors.

According to the shipping companies that did reply, waste water is not treated on-board. The passenger ferries that operate between the Danish straits and the passenger/car ferries that operate in the Gulf of Finland discharge sewage into the sewer network ashore. One shipping company reported that some chemicals are added to the sewage to prevent the formation of sulphuric hydrogen and their vessels are equipped with the chemical or biological waste-water treatment plants, which are not operational but are on standby.

3.1 Present situation

The main ports for passenger and cargo traffic in the Baltic Sea are presented in Figure 3-3. The main flow of cargo traffic follows the Swedish coastline and turns east towards the Gulf of Finland and St Petersburg on the eastern side of Gotland. Other cargo flows are directed to the Gulf of Bothnia and the ports of Riga, Gdansk and Klaipeda. The busiest passenger routes in the Baltic Sea area are the route across Öresund between Helsingborg and Helsingör with 10 M passengers per year, the route across Fehmarn Bælt between Rödby and Puttgarden with 7 M passengers, the route from Stockholm to Finland and between Finland and Estonia with 7 M passengers, and the route between Göteborg and Fredrikshavn with 2 M passengers (Figure 3-4). The routes from Sweden to Estonia, Lithuania and Poland have increased significantly in recent years, in both capacity and transportation; for example, there are more than 400,000 passengers per year on the route between Karlskrona and Gdynia (Baltic Maritime Outlook, 2006).

According to the statistics for 1998 the ten biggest passenger ports in the Baltic Sea were Helsingborg, Helsingør, Stockholm, Helsinki, Tallinn, Malmö, Göteborg, Fredrikshavn, Turku and Copenhagen. At that time, 35% of the 80 million annual ferry passengers recorded in Baltic Sea Region ports were going through the two ports of Helsingborg and Helsingør. In 2000 the biggest passenger ports were Helsingborg, Helsingør, Stockholm, Helsinki, Tallinn and Turku (Hanell et al., 2000).

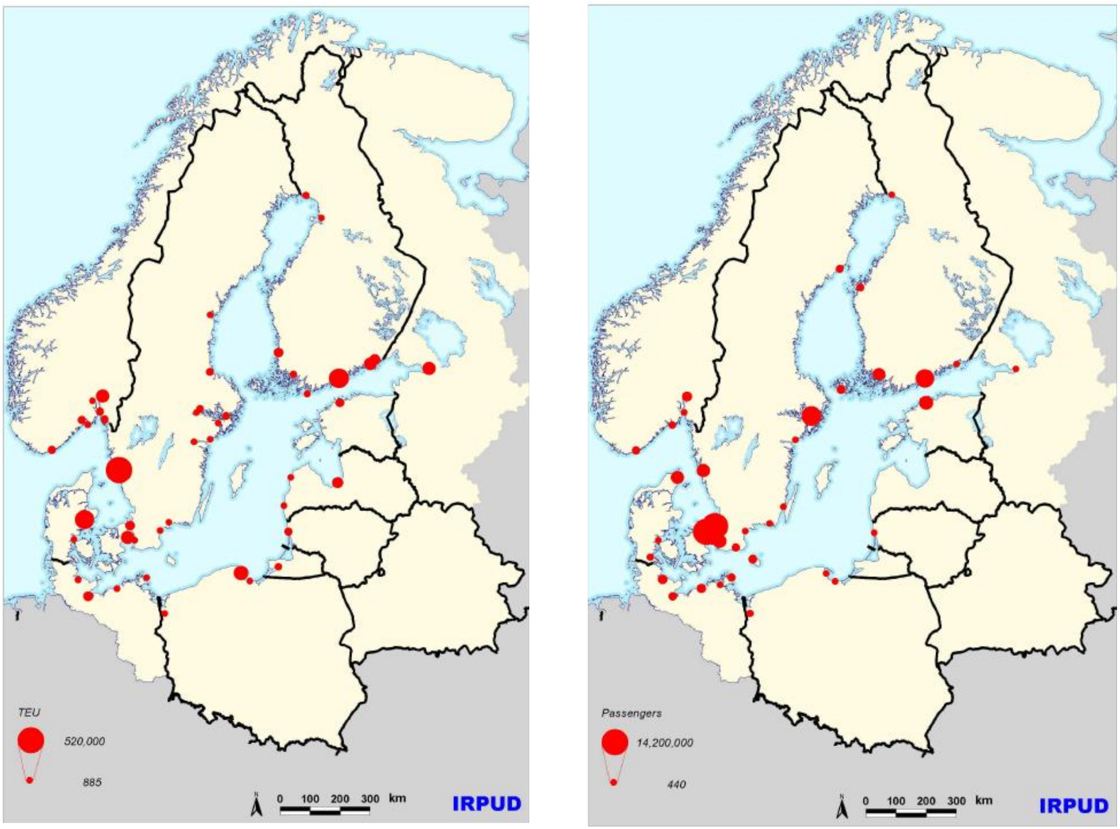

Figure 3-3. Container traffic (left) and passenger traffic (right) in the Baltic Sea area in 2000 (Hanell et al., 2000).

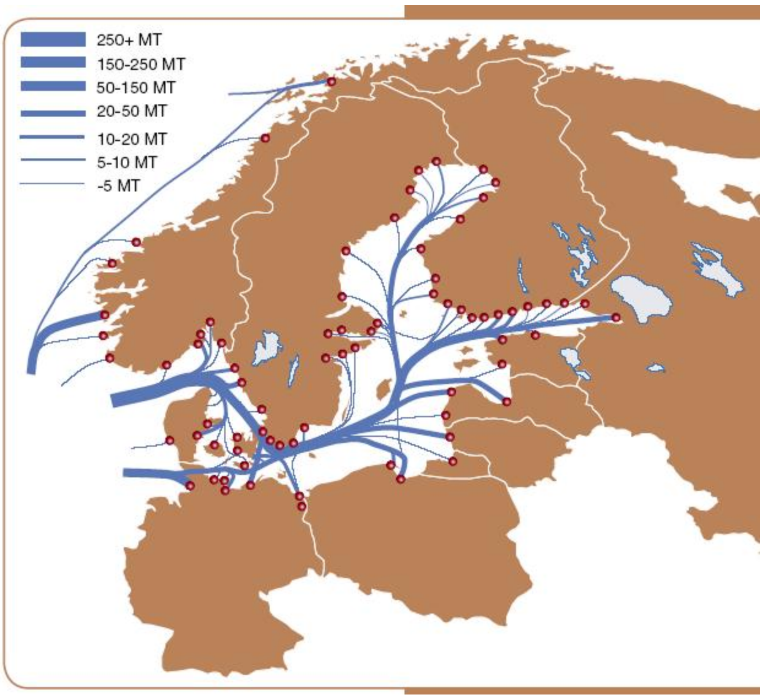

Figure 3-4. Passenger traffic and cargo routes in the Baltic Sea area in 2003 (Baltic Maritime Outlook, 2006).

In 1993 it was concluded that around 70 million passengers travelled on ferries in the Baltic Sea area, and that was regarded as a low estimate (SSPA, 1994). On the other hand, Wickens et al. (1994) estimated the number of passengers in the Baltic ferry traffic to be around 61 million.

The Swedish Maritime Administration have estimated that a little more than 235,000 trips were made by ferries and a total of about 53 million passengers were transported in 1998 (SMA, 1999). Hanell et al. (2000) concluded that, based on the 1998 figures, the number of passengers in the top 20 harbours was around 87 million.

The figures in Table 3-1 represent the number of passengers in the various ports based on the figures presented in the references and the data received from ports during the execution of the project.

Table 3-1. The number of passengers in various ports in the Baltic Sea area.

Port	**Number of passengers**		
	Ref.: Hanell et al., 2000[1]	Ref.: Kalli et al., 2005[2]	Information received from ports (2005 Figures)
Helsingborg	14,200,000		11,102,138
Elsinore (Helsingør, in 1997)	13,657,000		
Stockholm	9,300,000	9,643,000	10,900,000[3]
Helsinki	8,620,000	8,685,000	9,067,000
Tallinn	5,441,000		7,007,558
Malmö	5,300,000		
Gothenburg	4,600,000		
Fredrikshavn	4,305,000		2,930,093
Turku	4,229,445	4,101,577	3,770,000
Copenhagen	4,202,181		1,504,773
Oslo	2,493,000		
Kiel	2,100,000		
Rostock	1,813,450	2,160,000	
Rønne	1,379,521		1,560,000
Lübeck	1,300,000	371,547	
Kristiansand	1,117,551		
Marienhamn	-	1,100,000	
Ystad	1,000,000		
Sassnitz-M	997,230		761,008
Szczecin and Świnoujście	-	807,580	
Vaasa	820,040		90,000
Larvik	713,000		
Total	**87,588,418**		

When the inquiry results are compared to the statistics presented by Hanell et al. (2000) and Kalli et al. (2005), it can be seen that in most of the ports the passenger numbers have decreased during recent years. The passenger numbers in Hanell et al.'s report represent the situation in the late 1990s, when tax-free shopping between Scandinavian countries was still possible on a voyage. The EU ended the tax-free shopping on internal traffic on 1.7.1999, which can clearly be seen to have affected the passenger numbers. In addition, it is likely that the commission of the Great Belt Fixed Link between the Danish islands of Zealand and Fu-

[1] Figures for 1998.
[2] As an average number for the years 2001–2003.
[3] Figures for 2004, excluding the traffic in the archipelago.

nen across the Great Belt in 1998 also affected the passenger numbers, at least in Helsingborg, Helsingør, Copenhagen and Malmö.

On the other hand, the passenger numbers in Tallinn, Helsinki, Stockholm and Rostock have increased. One reason for this is the lower price level in Estonia and the release of alcohol importation after Estonia joined the EU in 2004. The increase in passenger numbers in the port of Rostock is probably due to the ferry connection from Hanko; the route opened in 2001 and car/passenger ferries operate daily between Hanko and Rostock.

An example of the ship type distribution in ports in the four Baltic Sea areas is presented in Figure 3-5.

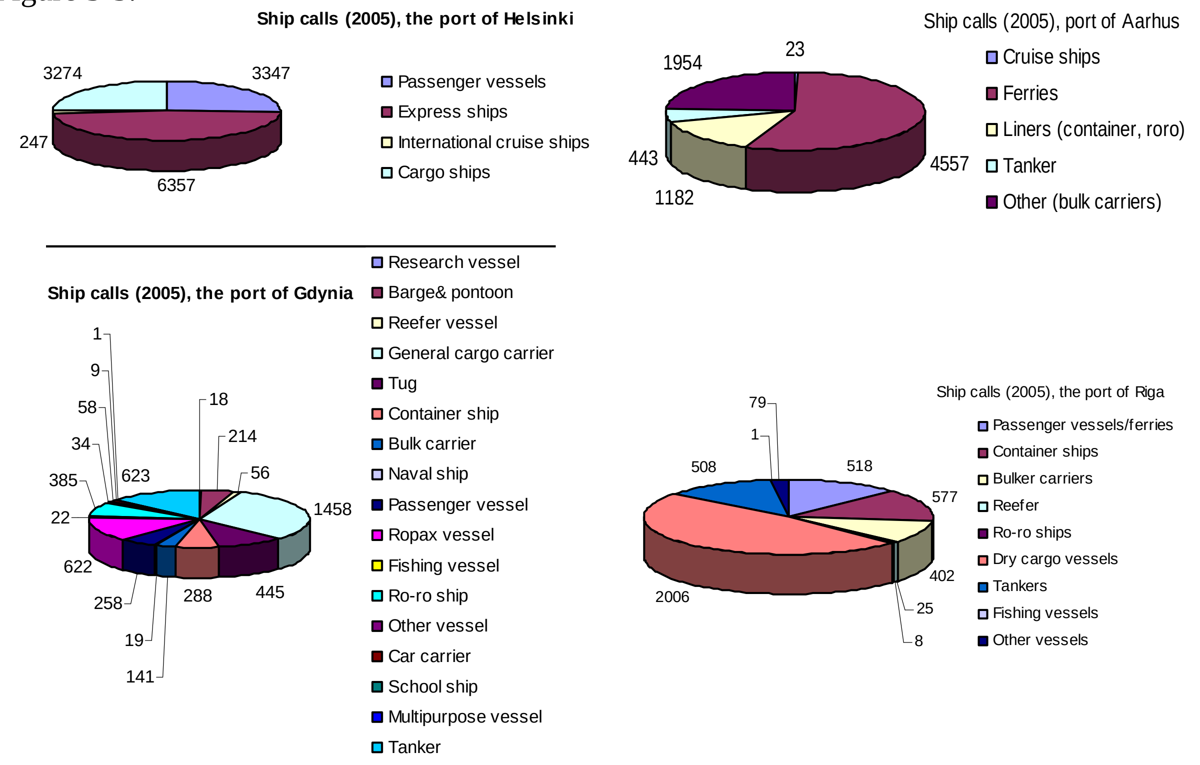

Figure 3-5. Example of ship type distribution in the Baltic Sea ports.

The maritime transport in the Baltic Sea region is directed from the northern ports to Germany. In 2003 the maritime transport in the Baltic Sea area totalled 178 M tonnes. Dry bulk was the largest commodity (75 M tonnes), followed by liquid bulk (62 M tonnes) and other cargoes (41 M tonnes). The oil and container trades are the fastest growing segments in the Baltic Sea area maritime transport (Baltic Maritime Outlook, 2006).

According to the reference (Saurama et al., 2008) totally 88.7 million passengers passed through 52 ports in the Baltic Sea in 2006. The busiest route for passenger traffic was the narrow channel between Denmark and Sweden. Ferry lines connecting Elsinore and Helsingborg had 10.7 million passengers. Half (51.4%) the passengers travelling on ferry or cruise vessels went through the five biggest passenger ports (Table 3-2).

Table 3-2. Top 20 passenger ports in the Baltic Sea in 2006 (Saurama et al., 2008).

1	Helsingborg	10,763,267	11	Rostock	2,541,144
2	Elsinore (Helsingør)	10,721,000	12	Gothenburg	2,199,150
3	Helsinki	9,045,502	13	Ystad	1,936,622
4	Stockholm	8,249,304	14	Trelleborg	1,696,646
5	Puttgarden/Fehmarn	6,789,335	15	Gedser	1,507,000
6	Rødby Færgehavn	6,789,000	16	Kiel	1,465,603
7	Tallinn	6,760,000	17	Rønne	1,409,000
8	Turku	3,162,612	18	Kappelskär	1,381,798
9	Mariehamn	2,681,114	19	Strömstad	1,250,160
10	Frederikshamn	2,594,000	20	Swinoujscie	929,899

Table 3-3. Number of passengers in two main ports in Finland.

	Number of departing passengers[4]	Number of arriving passengers[7]	Number of passengers[5]	Number of passengers[6]
Port of Helsinki	4,297,417	4,319,011	8,620,000	9,045,502
Port of Turku	1,826,692	1,829,247	4,229,445	3,162,612

When comparing the passenger figures provided by various harbours and the figures presented in the references (Hanell et al, 2000; FMA, 2008), it appears that the figures include both arriving and departing passengers (Table 3-3). In the reference (Saurama et al., 2008) this is clearly mentioned.

[4] Reference: Finnish Maritime Administration. 2008. Passagerartrafiken fördelad efter hamn åren 1973-2007. Figures from 1998.

5 Reference: Hanell, T., Bengs, C., Bjarnadóttir, H. & Spiekermann, K. 2000. The Baltic Sea Region Yesterday, Today and Tomorrow – Main Spatial Trends. Nordregio, Nordic Centre for Spatial Development. Figures from 1998.

[6] Reference: Saurama, A., Holma, E., Tammi, K. 2008. Baltic Port List 2006. Annual cargo statistics of ports in the Baltic Sea Region. A publication from the Centre for Maritime Studies, University of Turku. ISBN 978-951-29-3625-0 (pdf).

4 Waste-water management

4.1 Origin

Waste waters can be divided into oily and non-oily waste waters. Oily waste waters originate from engine rooms and machinery spaces, e.g. pump rooms. Oily waste water handling is regulated by the bilge water regulations in Annex I to the MARPOL 73/78 Convention. Oily waste waters are not included in this study.

Non-oily waste waters are divided into other non-contaminated drains and contaminated, “sewage type” waste waters. The non-contaminated waste waters are drainage waters from exposed deck scrubber systems, dedicated sprinkler drainage systems, AC room condensation collecting system, etc. These non-contaminated waste waters are also left out of this study (Salama, 2005).

The sources of contaminated waste water on-board ships are basically the same as in communities ashore. Annex IV to the MARPOL 73/78 Convention defines “Sewage” in the following way:

- drainage and other wastes from any form of toilets and urinals
- drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises
- drainage from spaces containing living animals
- other waste waters when mixed with the drainages defined above (for example a mix of sewage and grey water).

Sewage is also called black water and the discharge of ship sewage is restricted on the basis of the MARPOL 73/78 Convention. Sewage on-board ships differs from that of municipalities by its short retention time and smaller water content. On-board ship, the sewage ends up almost directly in the treatment plant; therefore the amount of dissolved BOD is lower than in municipal systems and the cleaning process is easier. The smaller water volume of the sewage on-board ship makes it more concentrated when compared to the municipal sewage (BMEPC, 1990; The Ocean Conservancy, 2002).

Grey water consists of non-sewage waste water, including drainage from dishwashers, showers, laundry, baths, galleys, and washbasins. Grey water represents the largest category of fluid waste generated by cruise ships. The discharge of grey water is not restricted by international law and in some cases it is discharged directly into the environment. However, in certain sea areas and during berthing the sewage and grey water must be stored or treated (BMEPC, 1990; The Ocean Conservancy, 2002).

The amount of waste water depends on the ship type. Passenger/car ferries usually leave the sewage ashore daily, so the storage of sewage on-board does not cause remarkable problems. On the other hand, cruise trips typically last for seven days and during that time waste has to be processed in such a way that environmental hazards are avoided and the orders of the authorities are fulfilled (Saari, 2005). When compared to passenger ships, RoRo-passenger (ropax) vessels have very modest sewage treatment systems. The shipowners' decision to discharge sewage into a PRF or to discharge black waters directly into the sea is based on the most economical way to fulfil the MARPOL requirements (Salama, 2005).

4.2 Quantity estimations

The quantity of black water (flush water excluded) can be estimated as 1.8 l per person per day. If the quantity of flush water is 10 litres at a time (gravitation system), the black water amounts to some 70 litres per person/day. The flux of the water varies considerably and the difference may range from 10 to 200 litres per person/day, depending on the sewage system. The smallest amount of waste water is gained with vacuum sewage systems, which generally produce 12 litres black water per person/day (BMEPC, 1990). The ocean conservancy has estimated the cruise ship black water production to range from 19 l to 38 l per person/day (The Ocean Conservancy, 2002).

Grey water amounts to approximately 120 litres per person/day (BMEPC, 1990). The ocean conservancy has estimated the cruise ship grey water production to range from 114 l to 322 l per person/day (The Ocean Conservancy, 2002).

Some estimates of waste-water generation have been presented in Salama (2005):

- toilet flush (gravity feed): 6–8 litres per flush
- toilet flush (vacuum feed): 1.2 litres per flush
- 1 min. shower: 12–14 litres
- total daily grey water accumulation: < 300 litres per day per person
- total daily galley and laundry accumulation: < 70 litres per day
- total daily black water accumulation in vacuum system: < 20 litres per day per person (Salama, 2005) or 8–12 litres per day per person (Bachér, 2001)
- in large cruise ships the vacuum system produces 20–30 m^3 black water per day (Bachér, 2001).

HELCOM Recommendation 11/10 gives guidelines for the capacity calculation of sewage systems on-board passenger ships (HELCOM, 1990). The total flushing systems used on-board ships are the conventional system and the vacuum system. The capacity calculations apply to passenger ships engaged in voyages with a length of more than 24 hours. They are based on the flow rate in litres per day per person. The calculations are presented in Table 4-1.

Table 4-1. Capacity calculations for sewage systems on-board passenger ships (HELCOM, 1990).

	Litres per person per day	
	Conventional system	Vacuum system
Sewage (black water)	70	25
Sewage and grey water	230	185

When compared to a municipal sewage treatment plant, the sewage that is treated on-board has a short retention time. The sewage load on-board can also vary considerably. In cruise ships the sewage loads are generally biggest in the morning and in the evening. These variations are balanced out by using holding tanks and dimensioning the treatment plants sufficiently large enough. The capacity of the holding tank is calculated using the following equation:

$$Cr \geq A \cdot Np \cdot Da, \quad (1)$$

where

Cr = capacity of the holding tank (m^3)

A = 0.06 (m^3/person/day), value of A may reduce according to the flushing system, etc.

Np = the total number of people on-board

Da = the maximum number of days operating in areas where the discharge of sewage that is not comminuted or disinfected into the sea is prohibited (minimum 1 day).

4.3 Treatment options on-board ships

Sewage can be processed with three principal methods: mechanical, chemical and biological. The treatment of sewage includes the following stages (Kiukas, 2005):

1. waste-water accumulation and management
2. waste-water pretreatment
3. waste-water oxidation
4. waste-water clarification and filtration
5. waste-water disinfection
6. sludge treatment.

The sewage treatment is usually a combination of the three principal methods, such as mechanical-chemical, mechanical-biological and chemical-biological. The choice of method depends on the purification aims and operating conditions (BMEPC, 1990). The estimates of the reductions in the BOD and phosphorus concentration for different types of treatment plants are presented in Table 4-2.

Table 4-2. The reduction estimates for different treatment types (BMEPC, 1990).

	Reduction in BOD	**Reduction in phosphorus**
Biological plant	80–95%	20–40%
Chemical plant	50–70%	75–90%
Simultaneous thickening	90–98%	75–90%
Physical sedimentation	20–30%	5–10%

An example of a combined biological and chemical disinfecting system is presented in Figure 4-1.

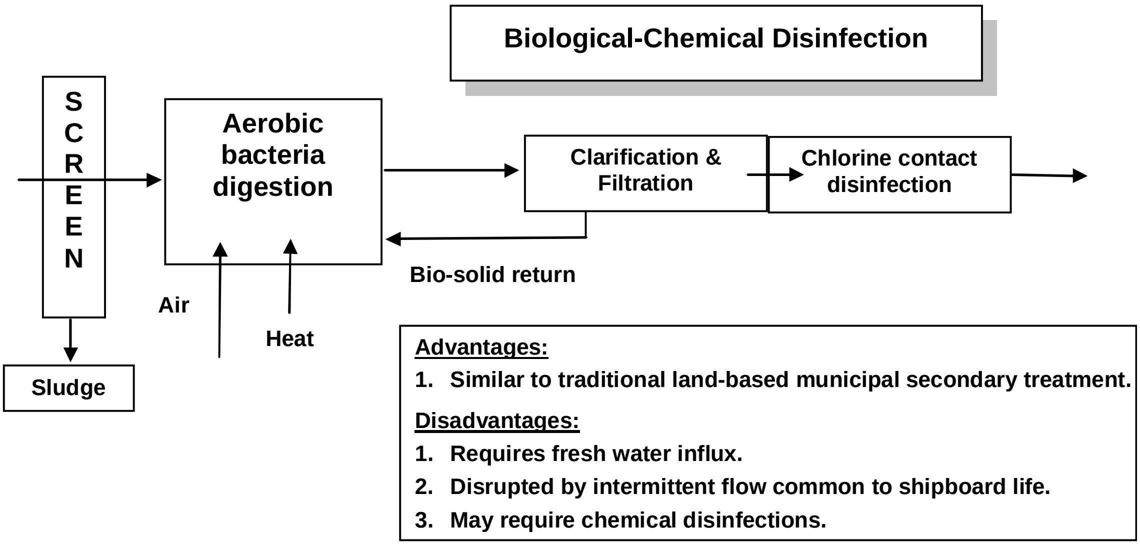

Figure 4-1. Simplified schematics of a biological-chemical disinfection (Eley & Morehouse, 2003).

Resolution MEPC.2 (VI) gives recommendations on international effluent standards and guidelines for performance tests for sewage treatment plants. The sewage treatment plant has to satisfy the effluent standards for its certificate of type test. The effluent standards include a faecal coliform standard, suspended solids standard and biochemical oxygen demand (BOD_5) (Resolution MEPC.2, 1976). In some cases even the amount of residual chlorine is restricted (Alaska waste-water regulations). The MEPC.2 (VI) resolution standards for waste-water quality are following:

- BOD_5: 50 mg/l
- TSS: 100 mg/l (shipboard test)
- Faecal coliforms: 250 cfu/100 ml.

It should be noted that the removal of nitrogen and phosphorus is not required. In the future, the limits for marine waste-water discharge may become closer to the land-based criteria. It is possible that the nitrogen and phosphorus concentration of discharged waste water will be limited.

The shipboard sewage treatment plant should be small, simple, reliable and have moderate running costs. The treatment plant should function well in all waste-water concentrations and during flow peaks. The plant should be also easy to maintain and operate, and fulfil current purification requirements. The plant operation highly depends on the technical personnel and the sewage being cleaned.

4.3.1 Waste-water pretreatment

Waste-water pretreatment protects the other phases of the purification process. Sewage contains a lot of solid waste and grease that may cause problems in the later stages of the process. The pretreatment process reduces the amount of solids in the waste water. Effective waste-water pretreatment also reduces the need for oxidation (Kiukas, 2005). The pretreatment is mechanical and consists of sieving and sedimentation units. The large particles pass through a shredding pump before sieving (BMEPC, 1990).

4.3.2 Oxidation

The mechanical filtering results in a maximum of 50% reduction in organic load. The remaining organic compounds have to be oxidized, either chemically or biologically.

Certain chemicals, e.g. ozone, chlorine, hydrogen peroxide, are added to the sewage in the chemical oxidation. The chemicals oxidize the organic impurities in the sewage water. When compared to the ozone and hydrogen peroxide, chlorine is not a very environmental friendly oxidant because of the carcinogenic compounds that develop as a by-product of the reaction. The added chemicals have an impact on the organic matter that has dissolved slightly and the BOD reduction remains small. The estimated treatment results for reduction in BOD and phosphorus are good (BMEPC, 1990).

Chemical oxidation is utilized in the macerator-chlorinating system that is used in the Unites States. The macerator-chlorinating system reduces bio solids through oxidation, dilutes the effluent with ambient seawater, and disinfects the sewage water with the help of an "electro catalyst" process (Figure 4-2).

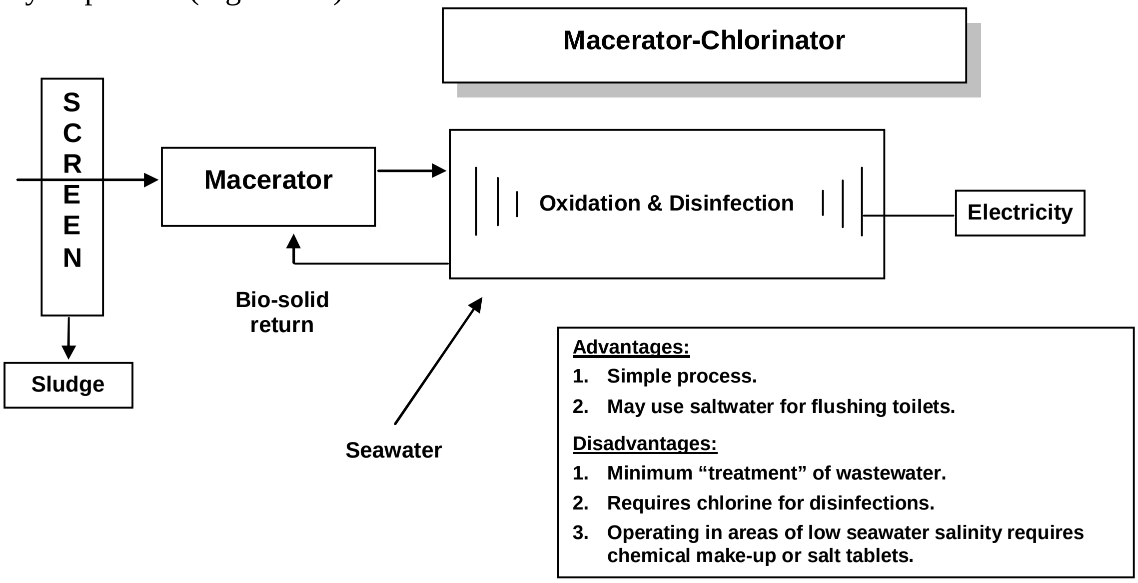

Figure 4-2. Simplified schematics of a macerator-chlorinator system (Eley & Morehouse, 2003).

The "electro catalyst" process produces sodium hypochlorite disinfectant from the salt in the seawater. Some operators add chlorine to the contact tank to ensure that the disinfection is complete. This "over-chlorination" results in high levels of residual chlorine in the discharge, which is lethal to marine organisms (Eley & Morehouse, 2003).

In the biological treatment the micro-organisms use the impurities in the sewage as their nourishment. There are several types of bioprocesses and the most common biological process is the active sludge treatment plant, where the sewage is mixed in a continuous-action aeration tank with active sludge. Biological filters and biorotors are also used as biological treatment plants. In these devices the bacteria that destroy the impurities attach to the filtering material. The biological treatment system is the most efficient way of reducing the BOD load. The estimated reduction in BOD is 80–95% and the reduction in phosphorus is 20–40%. The effectiveness of the bioprocess depends on the amount of active biomass and the bacteria living conditions. No additives are needed in the biological oxidation and the amount of sludge is small. The disadvantages of biological treatment are the long starting period and its sensitivity to external disturbances. The reasons for malfunction of the biological system are the following:

- Strong chemicals that have got into the plant are destroying the bacteria.
- Bacteria die due to the lack of oxygen when the ventilation does not work.
- The return of active sludge does not work.

When compared to the active sludge filter, the biofilters and biorotors are smaller in size, easier to start up, and recover from toxic shocks better. In addition, they have less energy consumption, better sludge sedimentation characteristics and better sustained loading variations (BMEPC, 1990).

4.3.3 Clarification and filtration

After oxidation, the sludge is separated in a sedimentation tank and returned to the aeration tank. Separating the active biomass, sediment particles and bacteria from the water is a critical phase in the waste-water purification process. The clarification and filtration processes used in the ships are membrane filtration, dissolved air flotation (DAF) and settling (Kiukas, 2005).

The DAF system relies on the injection of microscopic air bubbles into the feed water stream, causing the particles to float on the surface of a basin with inclined settling plates, from which they are continuously skimmed off and removed with a waste-water stream. It is useful when treating waters that are high in total suspended solids (TSS) or have highly variable suspended solids content (Ionics Incorporated, 2005).

4.3.4 Disinfection

The last phase in the waste-water purification process is disinfection. Depending on the previous treatment method, the disinfection enhances the quality of the waste water or is an essential part of the purification process. When the membrane clarification and filtration is used, the disinfection is performed with UV-light. If the water is very turbid, the UV-light is not suitable for disinfection. The other potential disinfectants are, for example, chlorine, radicals and ozone. With the help of these disinfectants it is possible to enhance the water purity even more (Eley & Morehouse, 2003; Kiukas, 2005).

4.3.5 Sludge treatment

The sludge production depends on the treatment process. Effective pretreatment before the bioreactor reduces the sludge production and enhances the sludge drying. The sludge that comes straight from the process is centrifuged. The centrifugal treatment raises the dry-substance concentration to 17–27%, compared to the before treatment dry substance concentration of 2–3%. After the decanter centrifuge, the possible sludge handling techniques are holding, incinerator, steam dryer, filter press or an alternative sludge conditioning process so that combustion is possible (Kiukas, 2005).

4.3.6 New technologies for waste-water purification

It said that the waste-water standards have distorted the development of treatment plants. Some plants collect sludge but do not destroy wastes. In the future the focus will be on systems that destroy wastes. Such systems could be purification through oxidation, chemical methods combined with sludge destruction, or biological-chemical methods such as simultaneous sedimentation. The advantages of biological-chemical treatment are a small amount of sludge, increased plant functionality and a good overall cleansing result. However, no method has proved so superior as to surpass the other methods (BMEPC, 1990).

Some treatment system manufacturers have provided advanced waste-water purification (AWP) systems that are designed to result in effluent discharges that are of a high quality and purity. Effluents meeting these high standards would not be subjected to the strict discharge limitations. AWP systems are at the development stage when it comes to performance and treatment costs (Saari, 2005; Salama, 2005). Generally advanced treatment systems utilize enhanced aerobic digestion with physical filtration to clean shipboard waste water. Other advanced treatment techniques are chemical treatment and mechanical decanting (Eley & Morehouse, 2003).

Moving bed bioreactor (MBBR) and flotation

MBBR is a bioreactor to which plastic carrier pieces have been added. These plastic carrier pieces maximize the area the bacteria can fasten onto.

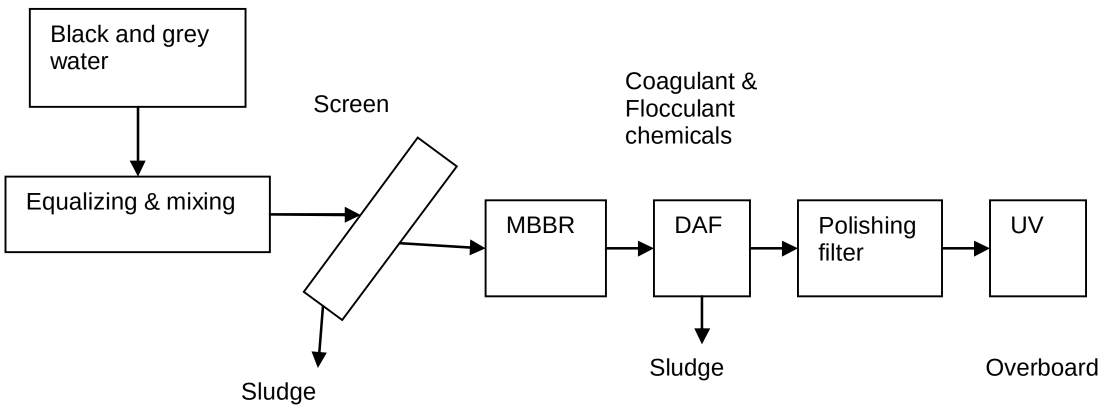

Figure 4-3. The principle of the moving bed bioreactor and flotation system (Kiukas, 2005).

In the MBBR there is no need to circulate the biomass back to the process. The sludge is separated after the bioreactor, either with the help of flotation or sedimentation. Because of the sludge separation, there is a great need for chemicals in the process and their adjustment is difficult. After the sludge separation there are still some particles in the water, so the water must be filtered before disinfection. (Figure 4-3) The advantages of MBBR are simple control of bioreactor, reasonable investment costs, well-known and reliable structure, and low solid and pathogen content in the effluent. The BOD_5 value in the treated water is quite small, below 5 mg/l (Kiukas, 2005).

Bio-reactor/filtration

These treatment systems consist of enhanced aerobic digestion and low-pressure membrane filtration. The systems emphasize either aerobic digestion or membrane filtration.

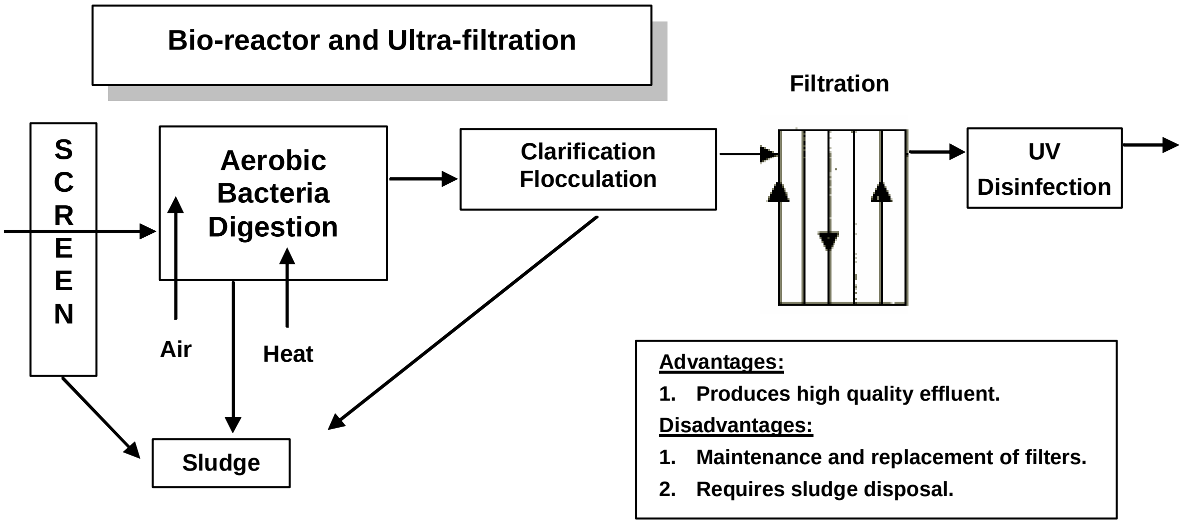

Figure 4-4. Simplified schematics of a bioreactor and ultra filtration (Eley & Morehouse, 2003).

All bio-reactor/filtration units use ultraviolet irradiation before discharge overboard or to a holding tank. The system produces solid sludge that must be properly handled and disposed of (Figure 4-4). The biggest problem with the membranes is their clogging. The maintenance frequency of the filters depends on their type and the capacity calculation of the bioreactor. Usually, the filters are cleaned by a back flush every twenty minutes or every six months. The filters of the MBBR reactor can be assembled externally or they can be submerged in the water (Eley & Morehouse, 2003).

External filters

When external filters are used the water is pumped through a filter pack or filter tube under pressure. Only 10% of the water is filtered and 90% returns to the bioreactor. External filters have higher energy consumption than the submerged filters. The disadvantages of external filters are their short exploitation time and their clogging. On the other hand, they are much easier to change than submerged filters (Kiukas, 2005).

Submerged filters

In submerged filters the water is filtered with the help of hydraulic pressure and filters' low internal pressure. Submerged filters have low energy consumption and are very durable, but they are difficult to change (Kiukas, 2005).

Activated oxidation process

This treatment process consists of a primary screening system, a primary solids separation and oxidizing system, a secondary oxidation tank, and controls and oxidant generation equipment (Figure 4-5).

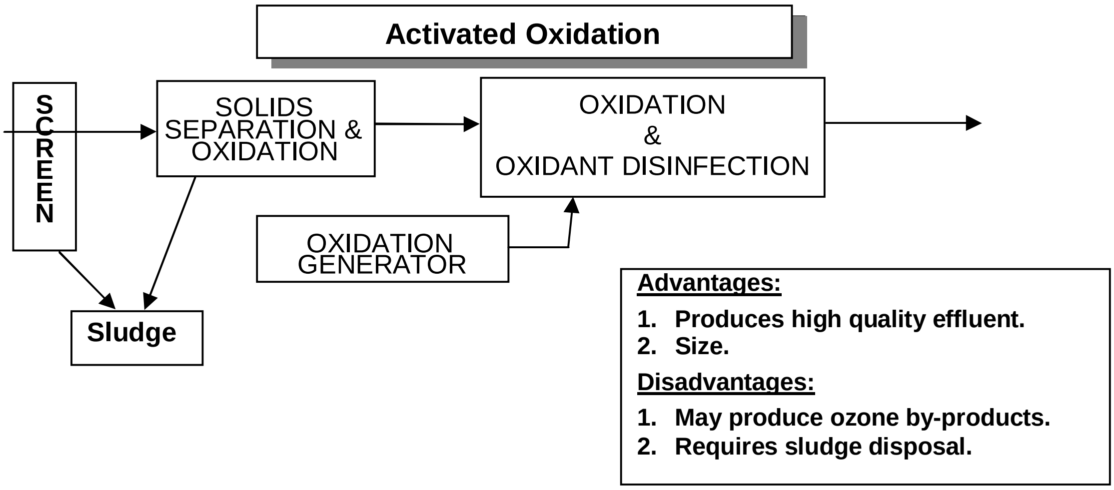

Figure 4-5. Simplified schematics of an activated oxidation (Eley & Morehouse, 2003).

Because the oxidants are produced electrically, there is no need for chlorine disinfection. The sludge is removed from the effluent using polymers. The sludge can be de-watered and incinerated on-board. The process is predicted to be less harmful to marine life than chlorine treatment because the ozone residuals dissipate quickly. The system has been tested in cruise ships (Eley & Morehouse, 2003).

Closed electro flotation

One of the innovations in waste-water treatment systems concerns the use of closed electro flotation. The test scale treatment plant is completely automatic and very reliable. The system is said to treat the black and grey water and produce drinkable water that can be reused. According to the field tests, the system reduces the nitrogen and phosphorus concentrations in the effluent by just fewer than 99%. The system also removes the dissolved matter and heavy metals. The system principle is presented in Figure 4-6.

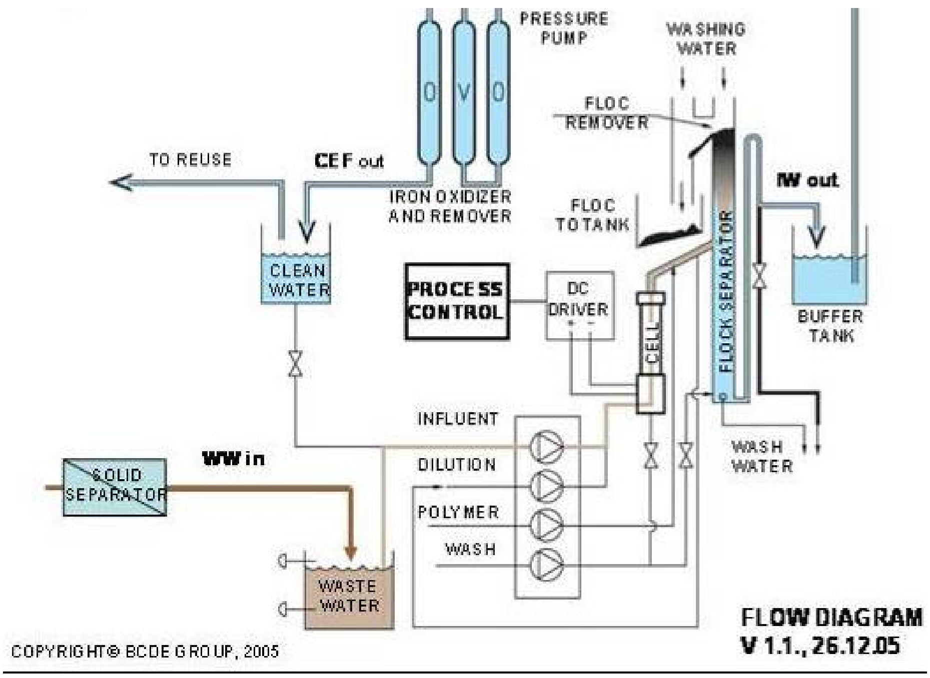

Figure 4-6. The principle of ECO-H20™ water purifier (Dynamic Design, 2006).

The closed electro flotation water purifier has only been tested on a laboratory scale so far, and the first treatment plant will most probably be installed on-board in October 2006 (Dynamic Design, 2006).

4.3.7 Grey water treatment systems

Reverse osmosis filtration

In the reverse osmosis filtration the grey water flows through a semi-permeable membrane into the pure water, after which it flows to the UV disinfection (Figure 4-7).

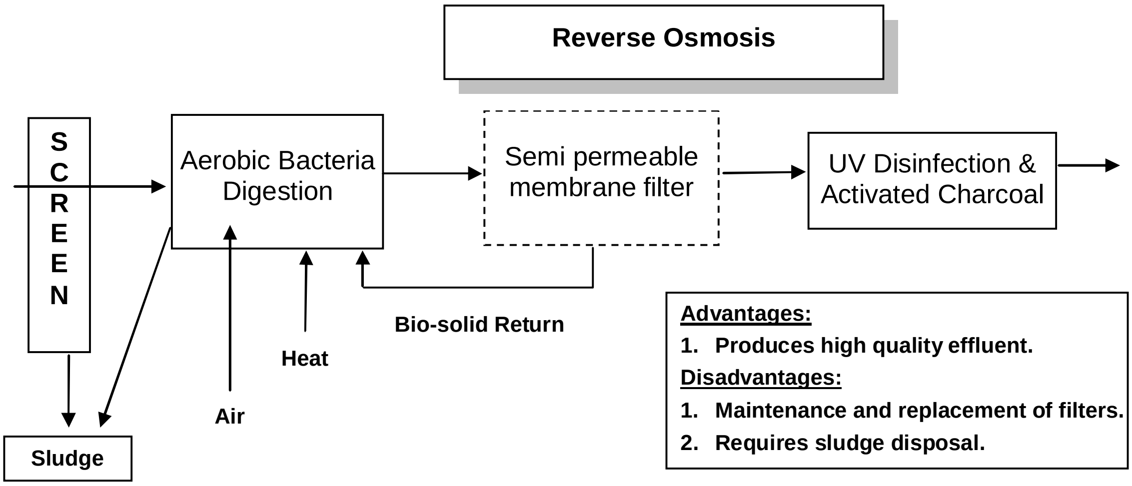

Figure 4-7. Simplified schematics of a reverse osmosis (Eley & Morehouse, 2003).

The treatment system has met the USCG standards for suspended solids and faecal coliforms. The system produces some sludge that must be incinerated, discharged at sea where legal, or landed ashore. Reverse osmosis treatment systems have been installed in cruise ships (Eley & Morehouse, 2003).

Electro coagulation

In electro coagulation aluminium and iron oxides are dissolved in the water. These oxides precipitate and flock the impurities from the water. The process produces radicals that oxidize the dissolved organic particles. The sludge is removed in the lamella separator (Kiukas, 2005).

4.4 Reception facilities

Ports are obliged to arrange reception facilities for waste that may not be discharged overboard. Reception of waste should not cause undue delays for ships. Ports need to ensure that the reception of waste is quick and easy, which encourages ships to leave waste ashore. The categories of waste that are to be received at ports are mentioned in the six annexes of the MARPOL 73/78 Convention (Table 4-3).

Table 4-3. MARPOL 73/78 categories of waste.

MARPOL 73/78 Annex	Category of waste	Entry in force
I	Oil	2.10.1983
II	Noxious liquid substances in bulk	2.10.1983
III	Harmful substances carried by sea in packaged form	1.7.1992
IV	Sewage	27.9.2003
V	Garbage from ships	31.12.1988
VI	Air pollution from ships	19.5.2005

Ports should have a waste management and handling plan in accordance with Directive 2000/59/EC. The treatment and disposal of ship-generated solid waste in ports should follow the national and local regulations of the port (Kalli et al., 2005).

Part of the traffic data collection from ports in the Baltic Sea area was to find out what kind of waste-water reception facilities ports offer to the shipping companies. In the passenger ports sewage from the ships can be pumped straight into the municipal sewer network; in the cargo ports the ships' holding tanks can be emptied into tank trucks.

5 Port Reception Facilities update (new chapter)

In order to get a better understanding of the status of the port reception facilities (PRFs) in the Baltic Sea area, an inquiry was sent to the *ad hoc* HELCOM Correspondence Group and also to the CLIA. This chapter contains the summary of the answers received by the Correspondence Group. The answers were received only from Finland, Sweden, Denmark and Poland.

The members of the *ad hoc* HELCOM Correspondence Group were invited to provide information on:

1. Voluntary discharge of sewage into PRFs in the ports of their country (the amount of sewage discharged into PRFs), and
2. Technical problems related to the discharge of sewage into PRFs.

In addition, an answer was received from the CLIA, which represents 24 member cruise lines that operate approximately 175 passenger vessels under various international flags. Member line vessels operate small vessels on coastal and riverine itineraries as well as large vessels on international and worldwide itineraries. Vessels range from approximately 50 passengers and a like number of crew up to 6,400 passengers and 2,200 crew (Genesis class, 2009). A vessel's capability to manage and treat discharges on-board varies hugely depending on the age and size of the vessel, the duration of its voyages, as well as the nature of its itineraries (Collins, 2008).

In addition, the European Cruise Council (ECC) provided information based on its experience concerning the availability of PRFs. The ECC represents the leading cruise companies operating in Europe. It aims to promote the interests of cruise operators with the EU institutions in all matters of shipping policy and ship operations, and also to promote cruising by the European public and encourage expansion of the European cruise market (ECC, 2009a).

5.1 The use of port reception facilities

New information on the amount of sewage discharged into PRFs was gathered.

5.1.1 Cruise ships

Cruise liners calling at Baltic ports seldom discharge their sewage waters into PRFs. The shipping companies usually believe that the advanced waste-water purification (AWP) systems that they have on-board the vessels are adequate even though they do not remove nutrients. Presumably the AWP system is used before discharging the waste waters into the sea.

According to the CLIA, cruise ships use approved waste-water treatment systems on-board to treat and discharge effluent in accordance with the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) requirements. They do not discharge untreated sewage anywhere in the world. Some vessels have attempted to discharge sewage into port facilities with mixed results: some ports indicating that they offer reception facilities for waste water have provided tank trucks or barges of insufficient capacity to accept cruise ship waste water during the few hours that the vessel is in port. Some have not provided information on the land-based treatment and thus it is not possible to determine whether treatment on land is of equal or superior quality as that performed on-board ship (Collins, 2008).

In its response the ECC reported that all ECC member line ships that visited the Baltic Sea in 2008 were equipped with either a Type II Marine Sanitation Device (MSD) or an AWP system. The ECC estimated that approximately a quarter of the ships had an AWP installed, and the ECC expects this percentage to increase in the future. Most of these systems use technology based on biological treatment, opting to discharge the treated waste water into the sea.

Furthermore, the response from the ECC states that, notwithstanding the requirement under EU Directive 2000/59 for adequate reception facilities throughout Europe, it is clear from the Cruise Baltic survey that there is an evident lack of such facilities for cruise ships operating in the Baltic (ECC, 2009b).

In the spring of 2008, the Port of Helsinki launched a campaign to increase the number of cruise liners that would opt to leave their waste water ashore. Even though the regular traffic passenger ships have long used this opportunity, to date it has been rarely used by cruisers. The service is free from additional charge (Helsingin Sanomat, 2008). All the cruise liners calling to Helsinki have been informed about the nutrient load problem in the Baltic Sea. By the end of June, at least one cruise company had engaged with the campaign. The Port of Stockholm was unable to co-operate with Helsinki on the campaign, since it still has some cruise quays that do not have the facilities to discharge the sewage from ships directly into the municipal waste-water treatment plant. In St Petersburg and Tallinn, sewage can be collected by truck service but it is not efficient in the case of cruise ships (Vuorivirta, 2008).

5.1.2 Finland

The following information was provided by the ESPO[7]/Finnish Ports Association concerning the Port of Helsinki (ESPO, 2008)**:**

- 234,305 m^3 of waste water were collected from RoRo-passenger ferries in 2007,
- 8 cruise vessels on 34 calls discharged sewage,
- total number of cruise vessels calls 238,
- RoRo-passenger ferries exempt from the mandatory delivery of waste used the port sewer network for discharging sewage.

The reference (Port of Helsinki, 2008) states that in all three harbours of the Port of Helsinki facilities exist to discharge the sewage from ships directly into the municipal waste-water treatment plant. Additionally, international cruise ships can leave their sewage onshore at Hernesaari and Katajanokka cruise quays. Discharging comminuted and disinfected sewage using an administration-approved system at a distance of more than 3 nautical miles from the nearest land, or sewage that is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land is permitted by law. When treated by an approved treatment system, ships are allowed to discharge sewage without restriction. Even though the legislation provides for discharging the sewage into the sea, more and more ships leave the black and grey waste waters to be treated onshore. Pumping the sewage onshore has created odour problems in and around the harbours. As a solution to this problem, the shipowners have started to pretreat the sewage on-board regular passenger traffic to Katajanokka. The effect of the pretreatment has been found to be positive (Port of Helsinki, 2008).

[7] European Sea Ports Association.

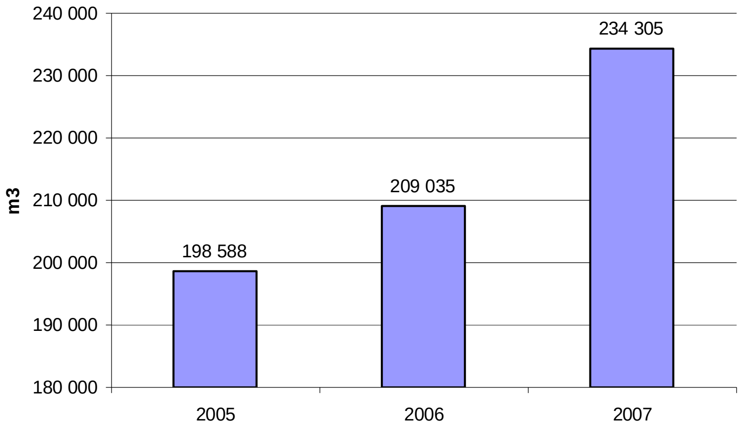

Figure 5-1 Waste-water amount pumped ashore from the ships in Helsinki 2005-2007 (Port of Helsinki, 2008).

Information concerning the other ports in Finland is given in Table 5-1.

Table 5-1. Information received on the amount of waste water collected in some Finnish ports.

Port of Hanko	0 m^3 in 2007, in previous years 20–40 m^3 per Superfast ferry visit
Port of Rauma	0 m^3, 2005–2006 total 40 m^3.
Port of Oulu	0 m^3 from international traffic, but port ice-breaker sewage water collected
Port of Kemi	0 m^3 from international traffic, M/S Sampo (old ice-breaker used for tourism) 62 m^3.

According to the Finnish Ports Association the total amount of sewage discharged into PRFs in Finnish ports was 348,681 m^3 in 2007. Some sewage was also discharged into sewage trucks (50+ m^3).

5.1.3 Sweden

Discharges of sewage into PRFs in Swedish ports:

Year	**Volume**
2003	330,000 m^3
2004	376,000 m^3
2005	874,843 m^3
2006	736,457 m^3

In Stockholm, the authority responsible for sewage collection from ships is not the port but the municipal water company (Vuorivirta, 2008).

5.1.4 Estonia

The Port of Tallinn gives the following information on its website:

In accordance with the effective legislation, prior to leaving the port a vessel shall discharge vessel waste and cargo-related residues generated at loading/discharging vessel. The requirement may be ignored if prior to leaving the port the utility rate of ship-generated waste in storage tanks remains under 25%. An obligatory waste fee shall be applied to all vessels calling at the Port of Tallinn, except for fishing boats, small crafts, military vessels and vessels performing state administrative tasks. The waste fee shall be levied for each vessel call and it does not depend directly on the amount of waste delivered. The Port of Tallinn has differentiated the waste fee in accordance with vessel type; the fee is based on a vessel's GT. In return for a waste fee the port shall accept vessel bilge water, faecal water, garbage, waste including oil products and oil, except for cargo residues. Cargo residues and cargo-related residues shall be received for a separate fee in accordance with the amount delivered. Ballast water cannot be delivered to the port (Port of Tallinn, 2008).

5.1.5 Poland

Poland's Maritime Office in Slupsk, in response to the inquiry on sewage discharged into the PRFs in 2007, stated that all the discharged sewage was collected by truck service, since no pipe network is available in the Polish harbours. The collected sewage was then treated in the municipal treatment plants or in private mechanical/biological sewage treatment plants. The information concerning the Polish ports is presented in Table 5-2.

Table 5-2. Information provided by the Poland's Maritime Office concerning sewage discharged into the port reception facilities.

Harbour	Type and number of ships registered/operated in harbour *	Number of merchant ships that called to a harbour in 2007	Amount of sewage discharged to PRFs
Darłowo	fishing ships (53), yachts (10), passengers vessels ** (2), other (5)	32	ca 15 m^3
Kołobrzeg	fishing ships (70), yachts (24), passengers vessels ** (5), other (4)	64	ca 225 m^3 - in total from passenger vessels
Ustka	fishing ships (83), yachts (11), passengers vessels ** (9), other (4)	4	27 m^3
Łeba	fishing ships (38), yachts (13), passengers vessels ** (8), other (4)	0	ca 30 m^3
Swinoujscie	n/a	n/a	448.90 m^3 - 1 passenger ship and 99 different ships (e.g. dredgers, barges, tugs etc.)
Szczecin	n/a		128 m^3 - 16 ships (1 tanker, 3 general cargo ships and 12 different ships)
Gdansk	3 961		85 m^3 - 24 ships
Gdynia	n/a	n/a	312 m^3
Police			7 m^3

* no RoRo-passenger ferries or Superfast ferries operated in this harbour.

** number of passenger vessels involved in short-distance voyages lasting about 1 hour each and usually shorter than 1.5 Nm from the port.

In the port of Gdynia it is not possible to collect sewage from ships mooring at the breakwater. In the ports of Szczecin and Swinoujscie the capacity of the installations as well as the number of companies contracted to receive sewage from ports is much greater than the amounts of sewage currently being discharged.

5.2 Technical problems related to port reception facilities

Information concerning technical problems related to the discharge of sewage into PRFs was received mainly from the CLIA, the Finnish Port Association and the ECC. The ports that replied to the *ad hoc* HELCOM Correspondence Group had few complaints concerning their own systems.

5.2.1 Comments from the CLIA and the ECC

Cruise ships rarely find reception facilities in ports sufficient in capacity and quality of treatment. Treatment on-board ship is frequently better than is available onshore, or one may find that the vendor accepts the waste, only to discharge it into the port without treatment (this is unacceptable to the cruise lines, therefore, promoting treatment on-board). Amongst the deficiencies of port vendors in meeting the needs of vessels are that they are sometimes unreliable (do not show up) are not equipped with certified hoses or communications equipment, or have not undergone emergency response training.

Discharge connections to a sewer are rare (the Port of Helsinki does have them but they are not always reliable). Discharge to shore has also been attempted in Copenhagen and in St Petersburg (by barge). Discharges to tank trucks require a constant supply of trucks since they each only hold 25-30 tonnes, with the ships' duty officers monitoring the connections all day/night (Collins, 2008).

According to the ECC response, Cruise Baltic has conducted a survey for the cruise industry concerning the adequacy of PRFs, and 25 ports representing all HELCOM countries were reviewed. The results indicated that 15 out of 25 ports had no direct shore connection available, while most ports utilized trucks to offload the waste waters from ships. This practice may be suitable for cargo ships or tankers but it is completely inadequate for cruise ships.

The ECC response remarked that the ship-to-shore interface for unloading waste water requires considerable improvement to ensure safe and environmentally responsible practices in line with those adopted by the International Shipping Management (ISM) code and the environmental policies and procedures adopted by ECC member lines.

The ECC is aware of a number of operators that have attempted to discharge ashore with various degrees of success depending upon the PRFs. While ECC member companies welcome the opportunity to use shore-based facilities, the vast majority of facilities available are inadequate to serve the cruise industry (ECC, 2009b).

5.2.2 Comments of the ESPO/Finnish Port Association

Sewage pumping has caused odour problems in areas around the Port of Helsinki. The South Harbour environmental permit stipulates that a solution has to be found to them. Also, hydrogen sulphide concentrations at the treatment plant pump station have been elevated which is an occupational hazard for the employees. The vessels are therefore required (by the Port and Helsinki Water) to pretreat the sewage (adding of chemicals/ozone) and the performance is checked through ongoing measurement of hydrogen sulphide. The results have been excellent.

Municipal treatment plants are sometimes reluctant to receive sewage from ships because of a fear of dangerous substances in sewage that would disrupt the biological treatment process at the plant.

Handling of ship sewage is more costly than for average community sewage. Ship sewage may contain, e.g., food scraps, which raise oxygen consumption at the plant. Treatment plants often require laboratory tests of the sewage (ESPO, 2008).

5.2.3 Comments from the ports

In Poland, small fishing harbours in particular do not have the technical possibilities to receive sewage directly into their sanitation systems. A common practice is the use of sanitation cars.

Denmark and Sweden replied that they have no specific information on any technical problems concerning discharges of sewage into PRFs.

5.3 Holding tank capacity and other relevant matters

Discharge of sewage in ports may not be a big problem, but there are several aspects to be considered. Thus, more information was sought concerning the ability of big passenger ships to store all sewage in their tanks while sailing in the Baltic Sea area, if it were required that all sewage should be discharged into PRFs in the Baltic Sea ports. If the current tank capacity is not sufficient, would it be possible to increase the holding tank capacity in existing ships in order to store all sewage before entering the next port of call in the Baltic Sea area? This information was sought from the CLIA and its reply was the following (Collins, 2008):

Cruise lines are open to discussing the use of PRFs, and will work with all concerned parties to determine how best to manage these wastes. It was requested that the following aspects be considered:

1. Capacity and Quality: Cruise ships make port calls during the day (peak hours) and there can be multiple cruise ships in port on the same day landing large volumes of waste water.
   - there must be adequate waste-water treatment capacity ashore,
   - the dock workers and equipment must be provided as soon as the vessel docks,
   - the effluent must be treated to quality levels above those already available on-board ship, and
   - the facilities must be operational on all days that vessels are in port.

2. Inadequate PRFs: Some ports attempt to provide vendor services (trucks, barges), however:
   - these are often not adequate in capacity to manage the large volumes from ships,
   - the sewage may be treated to lower standards than it would be on-board, or
   - the sewage may be discharged untreated into the sea by vendors unwilling to pay for treatment.

3. Assurance of Quality and Commitment: Improper disposal of waste water is not acceptable and we need assurances that some level of supervision is provided (government, organization) to ensure continued compliance with environmental regulations by the port and port vendors.

- the service needs to be reliable and timely so as to meet the operational needs of the vessels,
- hoses, connections, and other equipment must be certified to meet high standards to prevent a spill,
- reception stations must be manned and equipped with portable communications equipment in order to stay in touch with the vessel,
- the quality of effluent discharged from the land-based treatment facility must be monitored, and
- dock facilities must be available as soon as the vessel arrives to ensure that there is sufficient time to discharge all waste water ashore.

4. Compatibility with the ship treatment system:
   - advanced waste-water treatment (AWT) systems require nearly continuous operation to maintain the microbes in the bioreactor and have some holding capacity for treated water so as to not discharge it in port. The vessel cannot shut down these systems while in the Baltic Sea, but the effluent can be sent to holding tanks for a few hours. It is not clear if these systems have sufficient holding capacity to rely completely on discharging to PRFs.
   - these ships also operate outside the Baltic Sea, therefore, they must maintain the bioreactor at all times
   - vessels not using AWT systems use MSD Type II systems in accordance with MARPOL 73/78 Annex IV

Considering the possibility to increase the holding tank capacity, the CLIA replied (Collins, 2008):

> Every foot of space is assigned to a specific use, from the vessel conceptual design through construction and operation. To provide additional tankage for sewage would require that an equal amount of space be removed from another task on-board. These ships have been carefully balanced so the assignment of more space for tankage would likely result in another feature of the ship (power, HVAC, electrical generation, fuel and potable water capacity, fire fighting & damage control, storage, itinerary length, speed, turning radius, depth in the water, and so on) to be compromised. The only practical method, although not usually feasible, to increase tankage is to lengthen the vessel.
>
> Providing additional tank space also means holding water for longer periods of time, potentially creating a problem with bacterial growth. Waste-water treatment systems greatly reduce, but do not eliminate, bacteria. Even though the level of bacteria is very low, when that water sits in storage under wet and warm conditions there is the potential for regrowth. Storage of treated black water under these conditions is corrosive and can adversely affect ship structure, integrity and stability, potentially leading to safety concerns under the Convention for Safety of Life at Sea (SOLAS).

The ECC noted that waste-water holding capacity varies from ship to ship and is dependent on a number of design and operational factors that influence the capability. ECC member lines are reviewing their operational practices and will investigate optimizing the holding and treatment arrangements for the 2009 season. Where feasible, practicable and in the best interests of the environment, their lines will discharge effluent ashore. All of the foregoing activities by the ECC rely upon adequate port waste reception facilities being available (ECC, 2009b).

6 Supplier inquiry in May 2008 (new chapter)

VTT's commission in this report update was to investigate the availability of on-board sewage treatment plants that are capable of reducing discharges of nitrogen and phosphorus. The availability of such systems was studied by sending an inquiry to established suppliers of different kinds of solutions for water purification on-board ships.

The aim of the inquiry was to gather information concerning the availability and estimated costs of on-board waste-water treatment plants for the case study ship. The case study ship is a cruiser with a passenger capacity of 2,500 persons and a staff of 800 persons. The waste-water load (black and grey) is estimated to be 185 litres per person per day, and the ship is equipped with a vacuum toilet system. Both black and grey waste waters are to be treated on-board. The plant must be capable of reducing nitrogen (ammonium and total N) and phosphorus (soluble total P) loads from the sewage. The reduction rate [%] or target level [mg/l] was asked to be indicated.

The letter of inquiry, attached to the end of this report, was sent by e-mail to 13 companies listed in Table 6-1.

Table 6-1. The contact list used in the supplier inquiry.

Company	Contact person	E-mail
Aqua-Pure Ventures (NO)	Ivar Solvi	ivar.solvi@salsnes-filter.no
Evac (FI)	Jari Jokela	jari.jokela@evac.zodiac.com
Dynamic Design (FI)	Markku Saarikangas	markku.saarikangas@gmail.com
GEWATER	Leo Pearce	leo.pearce@ge.com
Gertsen & Olufsen (DK)	Jakob le Fevre	jaf@g-o.dk
HAMANN AG (DE)	Volker Jautelat	vjautelat@hamannag.com
Hamworthy (UK)	Martin Bentley	mbentley@hamworthy.com
Hansun	No contact person	info@hansun-marine.com
Hydroxyl Systems (CAN)	Steve DePoli	sdepoli@hydroxyl.com
Triton-Format (FR)	Henri Vuillermoz	henri.vuillermoz@triton-format.com
Triqua (NL)	No contact person	info@triqua.nl
Veolia / Krüger WABAG / RWO	Peter Boney	peter.boney@veoliawater.com
Zenon, Part of GE's Water & Process Technologies Business	Peter Ohle	peter.ohle@ge.com

The cover note for the inquiry was as follows:

VTT Technical Research Centre of Finland (www.vtt.fi/) has a commission from the ad hoc HELCOM Correspondence Group to investigate the availability of on-board sewage treatment plants that are capable of reducing discharges of nitrogen and phosphorus.

The aim of this enquiry is to gather information concerning the availability and estimated costs of on-board waste-water treatment plants for the case study ship. In addition all the views and comments related to on-board waste-water treatment plants you may have are welcome.

The results of this inquiry will be distributed to the HELCOM Correspondence Group in order to support its decision making.

We would appreciate it if you could respond to the attached inquiry by 9 May 2008. If you need more information relevant to this inquiry, do not hesitate to contact VTT.

6.1 Results

As a result of the inquiry only a limited amount of information was received concerning the availability of sewage treatment plants that are capable of reducing discharges of nutrients. Apparently, sewage treatment plants currently on the market are not specifically designed for this purpose. Three companies out of eleven replied to the inquiry, and the replies from Evac, Veolia and HAMANN AG are presented below. Only Evac provided a comprehensive response to the inquiry, while the other two replies did not contain detailed information.

6.1.1 Evac

Evac is a company that designs, manufactures and markets environmentally friendly waste and waste-water collection and treatment solutions for the marine industry worldwide. It provided a rather detailed quotation as part of its reply to the inquiry.

The quotation is a copy of a 3,300 people cruise vessel quote, modified for the purposes of the inquiry.

General presentation of the Evac MBR process (Evac, 2008)

The Evac MBR is a single-stream advanced waste-water treatment system where all the waste streams are treated in one process. The Evac MBR is based on effective equalizing and mixing of the incoming waste streams, pretreatment by screens, an aerated biotank and a membrane bioreactor. In this proposal, a nutrient-removal step is added to the basic process.

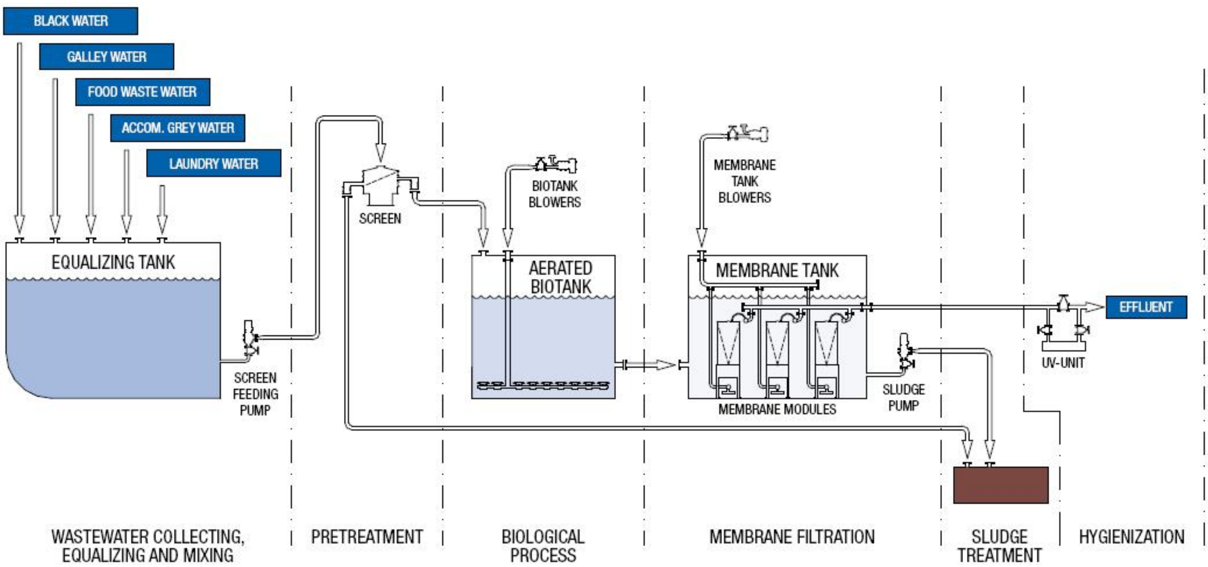

Figure 6-1. Basic principle of the Evac MBR single-stream process (Evac, 2008).

The Evac MBR process is fully automated and controlled through a PLC by vacuum/pressure switches, level switches, DO, TSS and pH sensors, flow meters and foam detectors. Membranes are of a submerged type, supplied by the Japanese company Kubota.

Description of design data and performance

Please note this remark from Evac: The Evac MBR process is designed by using Evac know-how on waste-water concentrations. In the Evac calculation there is also an approximately 30% “built-in” redundancy for the different waste-water characteristics between different ships and waste-water fluctuations. It should also be noted that a typical waste-water amount per person on a cruise ship is 250 litres/person/day (the calculation is based on a requested 185 litres/person/day).

The Evac process is calculated for following hydraulic loading:

- Black: 3,300 people * 15 litres/day = 49.5 m^3/day
- Galley: 3,300 people * 32 litres/day = 105.6 m^3/day
- Food waste: 3,300 people * 3 litres/day = 9.9 m^3/day
- Accommodation grey water 3,300 people * 110 litres = 363 m^3/day
- Laundry water 3,300 people * 25 litres = 82.5 m^3/day

Total daily nominal flow = 610.5 m^3/day.

The expected effluent BOD and TSS values are below 10 mg/l. On-board tests show that effluent from the Evac membrane process fulfils all current and future limits.

	IMO Marpol	IMO Marpol	USCG	Alaska	Navy NIAG	Rhein River	Evac MBR
	MEPC2	MEPC159(55)	33CFR 159 PT1-300	33CFR 159.309	2015 target		Test results
BOD_5 (Biochemical oxygen demand) mg/l	50	25		30	15	25	< 3
TSS (Total suspended solids) mg/l	50	35	150	30	50		< 5
COD (Chemical oxygen demand)		125				125	< 50
Faecal/Thermotolerant coliform cfu/100ml	250	100	200	20	100		BDL
Residual Chlorine mg/l				10	0		0
pH		6-8.5		6-9			within limits

The expected nutrient concentrations of effluent are:

Nitrogen: < 10 mg/l
Phosphorus: < 0.5 mg/l

Note: The limit set for the municipal waste-water plant in Viikinmäki (Helsinki) for total phosphorus is 0.3 mg/l (City of Helsinki, 2008). The limit for nitrogen was not given as such, but in 2004 the nitrogen concentration in cleaned water in Helsinki was 6 mg/l on average. In 2004, the phosphorus concentration in cleaned water in Helsinki was 0.33 mg/l on average (Helsingin Vesi, 2004).

Price

The price for one complete turnkey Evac AWP system is around 3-3.5 M€ per ship set. The installation is approximately 50% of the cost (turnkey retrofit).

Operational costs for 3,300 pax AWP

The estimated annual operational costs (including electric power, chemical, membrane and filter consumption, labour costs) are around 153,000 €. The major overhaul costs for an assumed 30 years' lifetime of the vessel, including costs of membrane replacement every 10 years (i.e. twice), are about 686,000 € (Evac, 2008).

6.1.2 Veolia

Krüger WABAG is part of Veolia Water, the Water Division of Veolia Environment, which is the world's leading water services company. It specializes in water treatment managed services for municipal and industrial customers. Through Veolia Water Solutions & Technologies and its subsidiaries, it is also the world leader in engineering, design and execution of construction projects for turnkey facilities and water treatment plants.

Of all German companies, Krüger WABAG is the one that can cite the largest number of references in the area of membrane technology for both drinking water and waste-water treatment facilities. As a manufacturer-independent plant construction company, Krüger WABAG has used in its plants both cross-flow and flat-sheet membranes from different manufacturers.

To ensure that outflow values for marine waste-water treatment plants continuously and safely meet the most up-to-date and stringent guidelines (Alaska and MARPOL clear water standards) the MEMROD® system is being successfully used on a variety of different ship types. The innovative aspect of this technology is its use of membranes, which are directly incorporated into a sludge reactor.

The MEMROD® LT technology is based on the WSMS process and was specifically adapted to conditions on ships. The MEMROD® LT technology ideally combines the advantages of the biological treatment of black and grey waste water as well as galley waste water with the benefits of the micro-filtration process. The arrangement of the filter elements in the reactor constitutes a reliable, space-saving and gentle method of filtrating waste water following the biological degradation of its contaminants. The process thus ensures that the effluent figures not only meet the Alaska levels, but also are significantly and permanently below those levels. This gives operators the confidence that they will safely meet all likely future legislation and provides them with a performance level that is far better than what conventional waste-water treatment technologies can offer.

For almost ten years, the MEMROD® LT technology has been established under the name of "WSMS" as a purification process in land-based municipal and industrial waste-water treatment facilities, where it has proved very successful. The effluent quality is so high that the treated waste water can be reused in industrial processes without any problem.

Veolia's waste-water treatment plants for ships sold until now were not designed to reduce nitrogen and phosphorus because it was not necessary but they are generally able to do so. Veolia has experience in land-based waste-water treatment plants for more than 40 years, where the reduction of nitrogen and phosphorus is normal. With small adaptations of the treatment plants for ships, reduction of nitrogen and phosphorus is possible (Veolia, 2008).

6.1.3 HAMANN AG

The reply from HAMANN AG was short and contained only this information (HAMANN, 2008):

We are a manufacturer and supplier of sewage treatment systems, which are certified in accordance with the current and future regulations such as IMO MARPOL (MEPC 115(51) and 159(55)), Alaska or Miami Dade, but to my knowledge we never got an official value for nitrogen and phosphorus. This was not necessary up to now.

6.2 Other relevant information

The HELCOM Correspondence Group members were also asked to make inquiries about the availability of sewage treatment plants capable of reducing discharges of nutrients (nitrogen and phosphorus). In addition, inquiries on the subject were made from the CLIA. The following comments were obtained from various countries and from the CLIA.

Comments from Germany

Sewage treatment plants using advanced membrane technologies are available on the market for use on-board ships. These plants are mainly used on-board modern passenger ships. Although these treatment plants are also capable of reducing the discharge load of nutrients by their biological processing, the reduction capacity has to our information never yet been tested on-board ships.

Such systems are known as so-called “de-nitrification treatment plants” and are used according to our information only in land-based municipal installations.

The common sewage treatment plant on-board ships (3-chamber biological treatment plant) is not able to significantly reduce the nutrients in the discharge line. Therefore any future requirements should only apply to new passenger ships and RoRo passenger ferries.

As an alternative, the sewage from these ships and also from cargo ships may be delivered to the PRFs.

Denmark and Sweden replied that they have no specific information of on-board systems that are capable of reducing nutrients.

Answer from the CLIA and the ECC:

The technology is coming, but is not yet here, to practically remove all nitrogen and phosphorus from grey and black waters.

- Some advanced waste-water systems remove these as a by-product of their operations and we welcome information from land-based treatment plants as to how successful they are in removing these from waste water.
- The CLIA has advised waste-water treatment manufacturers of our desire for systems to remove nitrogen and phosphorus and we await news of their progress.
- Ships are working with vendors to minimize the amount of phosphorus in cleaning products (laundry soap, ware washing soap, housekeeping supplies) as part of the continual improvement processes required by their environmental management system (EMS) (Collins, 2008).

The ECC mentioned in its response that reduction of nutrients is one of the ongoing projects with pilot plants and full-scale tests. ECC members are also investigating nutrient reduction options at source and are looking to optimize operational practices to reduce nutrient levels in effluent discharges. The ECC also has serious doubts both economically and technically on retrofit applications based on the figures presented for retrofit applications. From prior experience, the ECC considers it very ambitious that effluent of < 10 mg/l for nitrogen and <0.5 mg/l for phosphorus would be achieved with the currently available AWP systems (ECC, 2009b).

7 Ship-borne nutrient input into surface waters (updated)

7.1 Estimated nutrient load into the Baltic Sea area

The nutrient load calculations are based on the data collected from ports, shipowners and various references. As a result, it can be concluded that there are substantial fluctuations in the different studies and data collected. The aim of the calculations is to provide order-of-magnitude information regarding the nutrient load originating from ships in the Baltic Sea area.

The ship-borne nutrient load calculations are estimations of the current situation in the Baltic Sea area. The calculations in Table 7-1 are based on the following assumptions described as a theoretical worst case scenario:

- for ferries, 45[8] million passengers annually, average duration of 4[9] hours for one voyage
- for cruisers, 250 cruises annually, 3,000 passengers for each cruise, average duration of 10 days for one cruise
- for cargo vessels, 584,000 vessels annually (1,600 daily[10]), crew 15, average duration one day
- no waste water treatment on-board (0% reduction of N and P)
- all waste waters discharged into the sea
- nitrogen load 15 g/person/day and phosphorus load 5 g/person/day.

The coefficients for nitrogen (N) and phosphorus (P) have been defined in RIL (2003) as: the nitrogen content in sewage water is 12–15 g/person/day and the phosphorus content is 3–5 g/person/day.

Kirscmann et al. (1995) suggest that the nutrient load of human urine is 2.5–4.3 kg nitrogen per person per year (6.85–11.78 g/person/day), and 0.7–1.0 kg phosphorus per person per year (1.92–2.74 g/person/day). Additionally, the nutrient load of human faeces is 0.5–0.7 nitrogen per person per year (1.37-1.92 g/person/day) and 0.3-0.5 phosphorus per person per year (0.82–1.37 g/person/day). Thus, the nutrient load caused by human waste water would be around 8.22–13.7 g/person/day for nitrogen, and 2.74–4.11 g/person/day for phosphorus.

In SSPA (1994) it was concluded that 70 million passengers in 1993 could have discharged about 132 tonnes of nitrogen and 33 tonnes of phosphorus into the Baltic Sea. It appears that the figure used for passengers in the SSPA study includes both departing and arriving passengers.

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[8] Around 90 million passengers, calculated both in departing and arriving port.

[9] Reference, SSPA Maritime Consulting AB. 1994. Discharges of sewage and grey water from passenger ships in the Baltic Sea area.

[10] Reference: HELCOM, 2005. Overview of the ship traffic in the Baltic Sea.

Table 7-1. Nutrient input into the Baltic Sea from airborne and water-borne sources and from ships.

	Nitrogen		**Phosphorus**	
	[tonnes/year]	**[%]**	**[tonnes/year]**	**[%]**
Atmospheric deposition (HELCOM, 2005) [11]	264,100	26.1652	-	0
Water-borne input (HELCOM, 2005) [11]	744,900	73.7995	34,500	99.6568
Ship-borne nutrient load (SSPA, 1994)	132	-	33	-
Ship-borne nutrient load (Knuuttila, 2006)	438		99	
Ship-borne nutrient load	356	0.0353	119	0.3432
– *ferries*	*113*		*38*	
– *cruisers*	*113*		*38*	
– *cargo vessels, incl. tankers*	*131*		*44*	
Total load	1,009,356	100	34,619	100

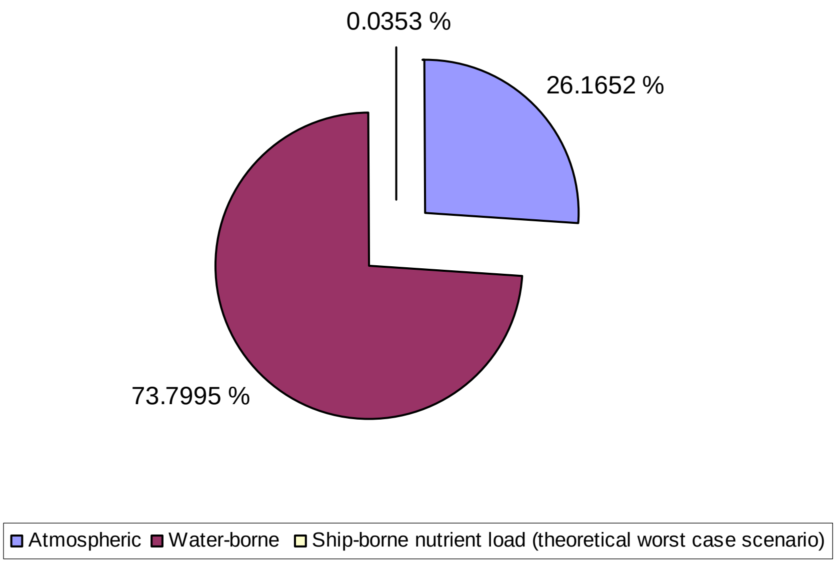

Figure 7-1. Total nitrogen input into the Baltic Sea.

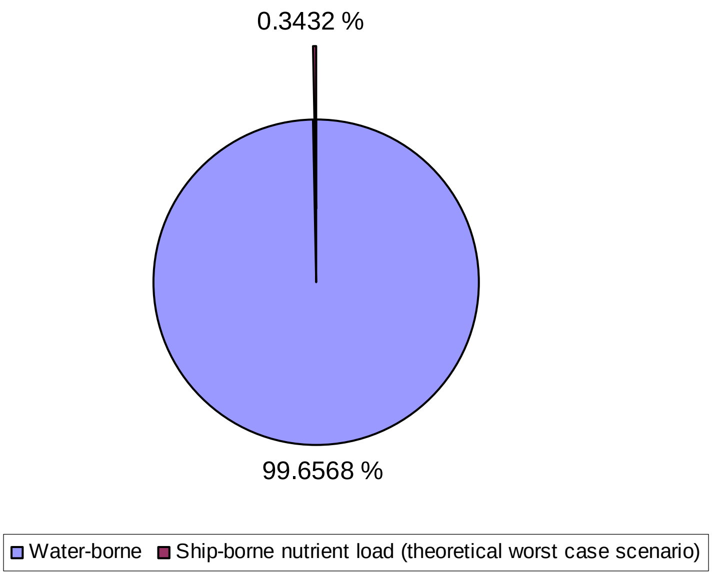

Figure 7-2. Total phosphorus input into the Baltic Sea.

[11] From the HELCOM countries in 2000.

The figures in Table 7-1 indicate that the nutrient input from ships' waste waters corresponds to about 0.0353% of the total nitrogen nutrient input (Figure 7-1) and 0.3432% of the total phosphorus input (Figure 7-2) into the Baltic Sea based on the data in the references and calculations conducted in this study. The airborne phosphorus has been estimated to be about 1–5% of the total phosphorus input (HELCOM, 2005).

The coefficients for the nitrogen and phosphorus load may fluctuate in different countries. For example, in Denmark the coefficient of nitrogen is 12 g/person/day and the coefficient of phosphorus is 2.7 g/person/day. If these values are used in the calculation, the nitrogen input into the Baltic Sea corresponds to about 0.0282% of the total nitrogen input and the phosphorus input to about 0.186% of the total phosphorus input.

In the scenario where all the ferries and cruisers operating in the Baltic Sea area would collect their waste waters on-board vessels and utilize the PRFs, the ship-borne nutrient load (Table 7-1) would decrease by around 63% (nitrogen and phosphorus). Correspondingly, the reduction rate in the Gulf of Finland (Table 7-2) would be around 90% for nitrogen and around 88% for phosphorus.

Additionally, the ECC provided valuable reference information concerning the nutrient load from cruise ships in the Baltic Sea area. In the ECC study it was concluded that 12 g/person/day for nitrogen and 3 g/person/day for phosphorus would be appropriate nutrient loads based on a study performed by the Ecological Sanitation Research in Sweden. The ECC study also used actual data on ships, which allowed more accurate determination of the cruise complement (defined as crew + maximum passengers) volumes.

In the ECC study it was calculated as 6.15 million days from 288 voyages using 63 ships with complement range from 154 to 4,813. According to the results the estimated nutrient load from cruise ships is 74 tonnes/year of nitrogen and 18 tonnes/year of phosphorus, which equals 0.007% for nitrogen and 0.052% for phosphorus from the total load. Consequently, the ECC study suggests that the passenger figures and the nutrient loads applied in the VTT estimations are too high and therefore lower figures should have been utilized (ECC, 2009b).

7.2 Estimated nutrient load into the Gulf of Finland

In order to estimate the nutrient load originating from ships' waste waters, a closer look at the Gulf of Finland was conducted. According to HELCOM (2005), the total phosphorus input into the Gulf of Finland area is around 5,370 tonnes and the total input of nitrogen is around 126,482 tonnes.

The nutrient load into the Gulf of Finland originating from ships' waste waters (Table 7-2) was estimated utilizing the following assumptions:

- for ferries, 5[12] million passengers annually, average duration of 4[13] hours for one voyage
- for cruisers, 250 cruises annually, 3,000 passengers per cruise and average duration of 3 days

[12] Around 10 million passengers, calculated both departing from and arriving at port.
[13] Reference, SSPA Maritime Consulting AB. 1994. Discharges of sewage and grey water from passenger ships in the Baltic Sea area.

– for cargo vessels, 26,600 vessels annually (73 vessels daily[14]), crew 15, average duration one day
– no waste-water treatment on-board (0% reduction of N and P)
– all waste waters discharged into the sea
– nitrogen load 15 g/person/day and phosphorus load 5 g/person/day.

Table 7-2. The estimated nutrient load originating from ships' waste waters into the Gulf of Finland.

	Nitrogen [tonnes/year]	[%]	**Phosphorus** [tonnes/year]	[%]
Atmospheric deposition (HELCOM, 2005) [15]	31,621	24,9901	0	0
Water-borne input (HELCOM, 2005) [15]	94,861	74,9686	5,370	99,6768
Ship-borne nutrient load	52	0,0413	17	0,3232
– *ferries*	*13*		*4*	
– *cruisers*	*34*		*11*	
– *cargo vessels, incl. tankers*	*6*		*3*	
Total load	126,534	100	5,387	100

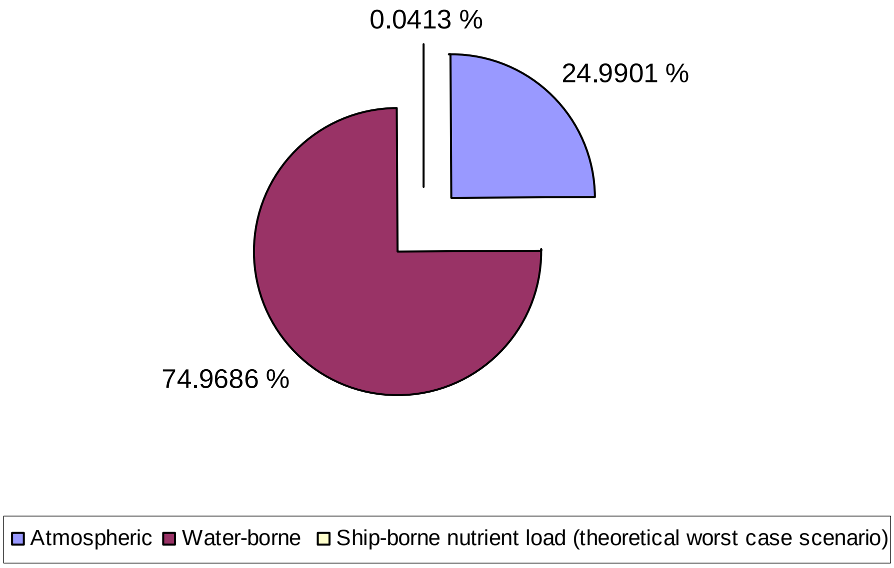

Figure 7-3. Total ship-borne nitrogen input into the Gulf of Finland area.

[14] Reference: Sonninen, 2006.
[15] From the HELCOM countries in 2000.

Figure 7-4. Total ship-borne phosphorus input into the Gulf of Finland area.

As a result of the estimation, it can be concluded that waste water originating from ships corresponds to 0.0413% of the total nitrogen input (Figure 7-3) and 0.3232% of the total phosphorus input (Figure 7-4) into the Gulf of Finland area.

It must be emphasized that the theoretical worst-case scenario normally applies to cargo vessels and cruisers, which represent a small proportion of the estimated passenger figures. According to the data received, the major passenger/car ferries collect their waste waters in holding tanks and utilize the reception facilities provided by ports. The rules concerning the discharge of sewage are presented in Chapter 9.

Pleasure craft were not included in the calculations since no updated information concerning the nutrient load from pleasure craft was available. The latest available data were from the beginning of the 1990s and included inland waters and sea areas in both Finland and Sweden (Knuuttila, 2006).

7.3 Nutrient load from ship-borne waste waters compared with other sources of nutrients in the Baltic Sea

When comparing the nutrient load originating from ship-borne waste waters, it is also relevant to be conscious of the fact that the exhaust gases from ships contributed 6% (equal to around 16,760 tonnes/year) of the total atmospheric deposition of nitrogen in the Baltic Sea in 2000 (Figure 5-5). Data on the deposition from shipping are based on the emissions in only one year (1990).

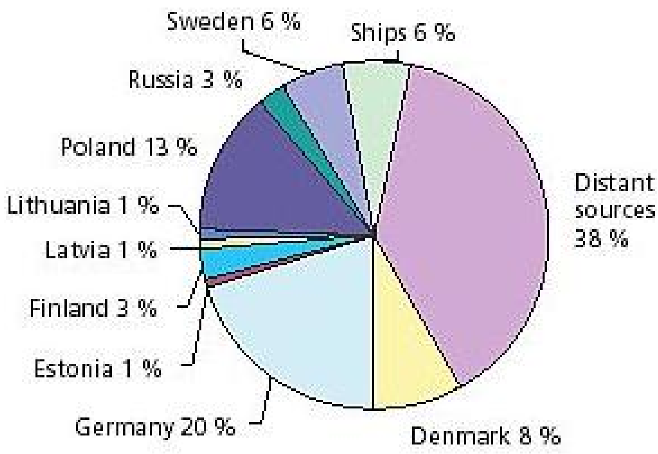

Figure 7-5. Proportion of atmospheric deposition of nitrogen in the Baltic Sea by HELCOM contributions in 2000. Note that the data ships' emissions only exist for 1990 and the same values have been used for all subsequent years (HELCOM, 2005).

Wahlström et al. (2006) refer to technologies for reducing emissions from ships, such as reduction by internal engine adjustments and engine process modifications, after-treatment technologies and alternative fuels and energy sources.

The municipal waste-water plant in Helsinki Viikinmäki deals with waste waters from 750,000 citizens in the Helsinki Metropolitan Area in compliance with the requirements set by the authorities. The limit for total phosphorus is 0.3 mg/l, and there is no set limit for total nitrogen in the Environmental Permit (City of Helsinki, 2008). In 2004, the nitrogen concentration in treated water in Helsinki was 6 mg/l on average (Helsingin Vesi, 2004). The following effluent rates for nitrogen and phosphorus into the Baltic Sea were achieved in 2005 (City of Helsinki, 2006):

- nitrogen (89% reduction): 1.7 g/person/day (equals to 479 tonnes/year)
- phosphorus (97% reduction): 0.1 g/person/day (equals to 24 tonnes/year).

According to the reference (Helsingin Vesi, 2007) the phosphorus load was 20 tonnes and nitrogen load 512 tonnes to the Gulf of Finland in 2007.

Nutrient loads from other municipal waste-water plants are presented in Table 7-3. When comparing nitrogen and phosphorus loads from the four coastal cities in Finland with ships' waste-water releases into the Gulf of Finland (Table 5-2), it can be concluded that the annual nitrogen load from the coastal cities presents a much higher amount while the phosphorus load appears to be about the same.

Knuuttila (2006) estimates that a ship with 2,000 passengers generates phosphorus load of 2 tonnes and a nitrogen load of 9 tonnes annually.

Table 7-3. Nitrogen and phosphorus loads from coastal cities in the Gulf of Finland in 2005.

Locality	**Nitrogen load [tonnes/year]**	**Phosphorus load [tonnes/year]**	**Population**
City of Hamina	66	0.9	22,000
City of Kotka	189	3.1	53,000
City of Porvoo	48	1.4	37,000
City of Espoo	439	15.5	295,000
Total	**742**	**20.9**	**407,000**
Ship-borne nutrient load into the Gulf of Finland	65	22	-

It should also be noted that fish farming contributes 1% (equal to 10.090 tonnes of nitrogen and 345 tonnes of phosphorus) of all the nutrient input into the Baltic Sea area. In Finland, 3% of the phosphorus load and 2% of the nitrogen load originates from fish farming (Varjopuro, 2000). According to Knuuttila (2006), the nutrient load from fish farming in Finland in 2005 was 688 tonnes of nitrogen and 85 tonnes of phosphorus, which mainly ended up straight into the Baltic Sea. Regional and local fish farming may have a significant consequence.

The outlet pipes from municipal waste-water treatment plants are significant point sources while waste waters from ships create a line load along shipping channels. In addition, the nutrients from ships' waste waters are immediately available for uptake by blue–green algae. Minimum requirements have been set for municipality waste-water treatment plants (Table 7-4). The values concerning the concentrations of total phosphorus and nitrogen refer to inhabitant equivalent.

Table 7-4. The minimum requirements for waste-water effluent from municipal waste-water treatment plants in Finland (RIL, 2003).

Parameter	**Concentration [mg/l]**	**Reduction rate min. [%]**[16]
Biological Oxygen Demand (BOD_7 in 20°C without nitrification)	30	70
Chemical Oxygen Demand (O_2)	125	75
Solids	35	90[17]
Total phosphorus	2 (10,000–100,000) 1 (> 100,000)	80
Total nitrogen	15 (10,000–100,000) 10 (> 100,000)	70

The Council of State in Finland has set the statute in order to reduce discharges from domestic waste waters and pollution of the environment. According to the statute (542/2003), the load from domestic waste waters must be reduced by 90% concerning organic matter (BOD_7), 85% concerning total phosphorus and 40% concerning total nitrogen compared with the untreated waste water. The statute applies to waste waters that originated from areas outside municipal water supply and sewerage systems. It is possible that in the future discharge limits of nitrogen and phosphorus will be set for waste-water treatment systems on-board ships.

[16] Calculated from load entering the waste-water treatment plant.
[17] Concentration and reduction rate are optional.

8 Uncertainties and data gaps (updated)

At the beginning of this study the ports and shipowners were sent an inquiry concerning the traffic flows in 2005. The purpose of the inquiry was to determine the current passenger numbers and the waste-water reception facilities in the Baltic Sea area. Unfortunately, the response rate to both inquiries was low, so the current passenger amount had to be estimated on the basis of source material. It was also impossible to estimate the relationship between the received waste water and the total waste-water accumulation from cargo and passenger traffic. The cargo ship companies did not respond to the inquiry at all, so the average journey time in the Baltic Sea had to be estimated based on the information available from various references. The average journey time for passenger ships in the Baltic Sea could be calculated from the responses.

While inadequate information was available for nutrient load calculations, several assumptions were made during the execution of the project. Nutrient load factors were based on the coefficients that are used for onshore waste treatment plants. The number of passengers was estimated utilizing several references and data received from ports. The average duration of one voyage was estimated based on SSPA (1994) and the responses received from ports. The number of cruisers and the duration of one cruise are based on the data obtained from ports and shipping companies. The number of cargo vessels and the number of crew are based on the HELCOM data. In addition, it was assumed that no reduction in nitrogen and phosphorus would be achieved and that all waste water originating from ships would be discharged directly into the sea. As a result of the several assumptions discussed above, a theoretical worst-case scenario was generated. This scenario normally applies to cargo vessels and cruisers since, according to the references; the major passenger ships do not discharge waste waters into the sea.

In the follow-up study, the intention was to determine the current situation of the waste-water reception facilities and their usage in the Baltic ports. Also, the availability and estimated costs of on-board sewage treatment plants capable of reducing discharges of nitrogen and phosphorus were investigated. The means used in the investigation were inquiries made by the *ad hoc* HELCOM Correspondence Group and the authors of this report from VTT.

Information about the PRFs, their usage and problems related to PRFs were received from only a few countries in the Baltic Sea area. In addition, the CLIA and the ECC shared their opinions on the subject, providing important information about how the users of the facilities perceive these things. Unfortunately, the response rate to the supplier inquiry was poor; only one supplier gave an extensive quotation containing the sought data on the target level of nutrients as well as the estimated costs of the treatment system. As the removal of nutrients is not yet required, the solutions are scarce.

9 Waste-water legislation

The environmental regulations for shipping can be divided into the following levels:
- international regulations and conventions (MARPOL)
- regional conventions (Helsinki Convention, EU directives)
- national legislation
- local regulations and recommendations.

9.1 International regulations and conventions

Revised Annex IV of MARPOL 73/78. Regulations for the prevention of pollution by sewage from ships

The United Nations International Maritime Organization (IMO) sets international maritime vessel safety and marine pollution standards. Based in London, the IMO comprises representatives from 152 major maritime nations. The IMO has adopted the 1973 International Convention for the Prevention of Pollution from ships, as modified by the Protocol of 1978. This Convention is known as MARPOL 73/78. The MARPOL Convention contains protocol articles and six technical annexes. The original MARPOL protocol was signed on 17 February 1973, but never entered into force. The current protocol is a combination of two treaties (1973 and 1978), and over the years has been modified by many amendments. It entered into force on 2 October 1983.

The revised annex IV of the MARPOL 73/78 Convention and its later amendments concern the prevention of pollution by sewage from ships. The national legislation that regulates the prevention of pollution by sewage from ships in the Baltic countries is based on the content of the MARPOL 73/78 Convention. All Baltic Sea countries are parties to the Convention (Wikipedia, 2006).

The regulations for the prevention of pollution by sewage from ships apply to the following ships that are engaged in international voyages:

- new ships of 400 gross tonnage and above
- new ships of less than 400 gross tonnage that are certified to carry more than 15 persons.

Five years after the new annex entered into force (1^{st} of August 2005), the regulations also applied to existing ships of 400 gross tonnages and above, and existing ships of less than 400 gross tonnage that are certified to carry more than 15 persons.

According to Regulation 9, every ship shall be equipped with one of the following systems:
- a sewage treatment plant
- a sewage comminuting and disinfecting system for the temporary storage of sewage when the ship is less than 3 nautical miles from the nearest land

- a holding tank of sufficient capacity for the retention of all sewage, having regard to the operation of the ship, the number of persons on-board and other relevant factors.

Standard dimensions for the discharge connections are presented in Regulation 10.

Discharge of sewage into the sea is prohibited in Regulation 11 of MARPOL 73/78 Annex IV with the following exceptions:

- The ship is discharging comminuted and disinfected sewage using a system approved by administration at a distance of more than 3 nautical miles from the nearest land, or sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land, provided that, in any case, the sewage that has been stored in holding tanks shall not be discharged instantaneously but at a moderate rate when the ship is en route and proceeding at not less than 4 knots; the rate of discharge shall be approved by the Administration based upon standards developed by the Organization.
- The ship has in operation an approved sewage treatment plant that has been certified by the Administration to meet the operational requirements and the test results of the plant are laid down in the ship's International Sewage Pollution Prevention Certificate. Additionally, the effluent shall not produce visible floating solids nor cause discoloration of the surrounding water.

Regulation 11 shall not apply to the discharge of sewage from a ship necessary for the purpose of securing the safety of a ship and those on-board or saving life at sea, or the discharge of sewage resulting from damage to a ship or its equipment if all reasonable precautions have been taken before and after the occurrence of the damage for the purpose of preventing or minimizing the discharge.

In 2006 the IMO's sub-committee on bulk liquids and gases has made amendments to MARPOL 73/78 Annex IV Regulation 11 concerning the discharge of sewage to include un-treated sewage from spaces containing live animals (IMO, 2006):

- A standard rate of discharge of untreated and undiluted sewage from holding tanks of 1/200,000 of hourly swept volume as a maximum permissible discharge, which should apply to all ships, and a swept volume definition for the discharge of un-treated and undiluted sewage from holding tanks that is not comminuted or disinfected as "ship breadth x draught x distance travelled".
- The standard rate for the discharge does not apply to sewage that is comminuted or disinfected that may be held in holding tanks.
- No recording requirements for sewage discharges under Regulation 11.1.1 of the revised MARPOL Annex IV are necessary.

Marine Environment Protection Committee: International effluent standards and guidelines for performance tests for sewage treatment plants

The Resolution of the Marine Environment Protection Committee (MEPC) gives recommendations on international effluent standards and guidelines for performance tests for sewage treatment plants / MEPC.2 (VI). The international effluent standards the sewage treatment plant should satisfy are:

- Faecal coliform standard: the geometric mean of the faecal coliform count of the samples of the effluent taken during the test period should not exceed 250 faecal coliforms/100 ml M.P.N (most probable number) as determined by a multiple tube fermentation analysis or an equivalent analytical procedure.
- Suspended solids standard:
  a) Where the equipment is tested onshore, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period shall not exceed 50 mg/l.
  b) Where the equipment is tested aboard ship, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period shall be not more than 100 mg/l above the suspended solids content of ambient water used for flushing purposes.

In addition, the plant should be so designed that the geometric mean of 5–6 day biochemical oxygen demand (BOD5) of the samples of effluent taken during the test period does not exceed 50 mg/l. The test standards for sewage treatment plants are given for onshore under shipboard simulated conditions or on-board ship under actual operating conditions.

In 2006 the IMO's sub-committee on bulk liquids and gases made amendments to resolution MEPC.2 (VI) (IMO, 2006). The current effluent standards the sewage treatment plant should satisfy are:

- The geometric mean of the thermotolerant coliform count of the samples of effluent taken during the test period should not exceed 100 thermotolerant coli-forms/100 ml as determined by membrane filter, multiple tube fermentation or an equivalent analytical procedure.
- The geometric mean of the total suspended solids content of the samples of effluent taken during the test period shall not exceed 35 mg/l.
- Where the sewage treatment plant is tested on-board a ship, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period shall not be more than 70 mg/l above the suspended solids content of ambient water used for flushing purposes.
- The sewage treatment plant shall be designed to reduce both soluble and insoluble organic substances to meet the requirement that the geometric mean of 5-day Biochemical Oxygen Demand (BOD5) of the samples of effluent taken during the test period does not exceed 25 mg/l and the Chemical Oxygen Demand (COD) does not exceed 125 mg/l. Appropriate methods may include COD Manganese and/or COD Chromium.
- The pH of the samples of effluent taken during the test period shall be between 6 and 8.5.

Concerning the raw sewage quality, the effluent concentration of total suspended solids should be no less than 500 mg/l in the on-board and onshore testing. It should be noted, that the nutrient concentration of treated sewage is still not limited.

9.2 Regional conventions (Helsinki Convention, EU directives)

HELCOM recommendations

HELCOM has given guidelines on the sewage treatment systems and the capacity calculation of sewage treatment systems on-board passenger ships (Recommendation 11/10).

HELCOM has made amendments to Annex IV "Prevention of pollution from ships" to the Helsinki Convention (HELCOM, 1992b). The amendments place an obligation on Contracting Parties to apply the provisions of Annex I-V of MARPOL 73/78. Additionally, it includes some requirements for ships other than those referred to in Regulation 2 of Annex IV to MARPOL 73/78. The instructions to report inadequacies of reception facilities for sewage are presented in the HELCOM Recommendation 10/6 (HELCOM, 1989).

HELCOM Recommendation 26/1 regards the application of the no-special-fee-system for ship-borne wastes in the Baltic Sea area. The guidelines were adopted in 2005. The "no-special-fee" system constitutes a system with the dual purpose of encouraging ships to deliver waste ashore and to avoid undesirable waste streams between ports, thereby encouraging a sound sharing of the waste burden. The no-special-fee system is one of the prerequisites for a substantial reduction in the number of operational and illegal discharges and thus for the prevention of pollution of the marine environment from ships. HELCOM recommends that the governments of the Contracting Parties aim to establish a harmonized "no-special-fee" system for the operation of reception facilities in their ports as of 1 January 2000 for ship-borne wastes covered by Annex I (oily wastes from machinery spaces) to MARPOL 73/78 and as of 1 January 2006 for wastes covered by Annex IV (sewage) and Annex V (garbage) to MARPOL 73/78. According to HELCOM, the governments of the Contracting Parties should also support or seek active co-operation with the North Sea States for the purpose of establishing a similar "no-special-fee" system in the North Sea Region (HELCOM, 2005).

Directive 2000/59/EC of the European Parliament and of the Council of 27 November 2000 on port reception facilities for ship-generated waste and cargo residues – Commission declaration

The purpose of the Directive is to reduce the discharges of ship-generated waste and cargo residues into the sea, especially illegal discharges, from ships using ports in the Community, by improving the availability and use of PRFs for ship-generated waste and cargo residues, thereby enhancing the protection of the marine environment. The Directive applies to all ships, including fishing vessels and recreational craft, irrespective of their flag, calling at, or operating within, a port of a Member State, with the exception of any warship, naval auxiliary or other ship owned or operated by a State and used, for the time being, only on government non-commercial service; and all ports of the Member States normally visited by ships. According to the Directive, Member States shall ensure the availability of PRFs adequate to meet the needs of the ships normally using the port without causing undue delay to ships.

9.3 Examples of national legislation

As mentioned before, the regulations concerning the prevention of pollution by sewage from ships in Finland and Sweden are based on the MARPOL 73/78 Convention. In Finland the valid decree on preventing water contamination caused by ship traffic in Finnish waters came into force in 1993. In Sweden a similar valid decree is presented in the Statutes of the Swedish Maritime Administration (SJÖFS 2005:8), dated 2005 (SJÖFS, 2005).

9.4 Local regulations and voluntary measures

Cruise industry waste management practices and procedures

The members of International Council of Cruise Lines are committed to protecting the environment by using waste management technologies and procedures. In the case of grey water, ICCL member lines have agreed that grey water will only be discharged while the ship is underway and proceeding at a speed of not less than 6 knots; that grey water will not be discharged in port and will not be discharged within 4 nautical miles of the shore or such other distance as agreed to with the authorities having jurisdiction or provided for by local law experts in an emergency, or where geographically limited. Member lines have further agreed that the discharge of grey water will comply with all applicable laws and regulations. ICCL members have agreed that all black water will be processed through a marine sanitation device, certified in accordance with US or international regulations, prior to discharge. Discharge will only take place when the ship is more than 4 miles from shore and when the ship is travelling at a speed of not less than 6 knots (ICCL, 2005).

10 Future scenarios (updated)

The EU's White Paper on Transport includes an intention to develop maritime transport to become more competitive as a transport alternative and to integrate maritime transport into the whole transport chain in a more efficient way. Some estimates of the future freight flows in the Baltic Sea area have been presented in Baltic Maritime Outlook (2006). Transport by sea is expected to grow by 64% between 2003 and 2020. In 2020, shipping is expected to become the leading mode of transport in international Baltic Sea regional trade, carrying 54% of the total volume of internationally traded goods, compared with 48% in 2003.

The predicted increase in maritime transport in the Baltic Sea area is based on growing port capacities, modernization of cargo carriers and improved environmental and safety values in the maritime transport chain (Baltic Maritime Outlook, 2006).

COWI (1998) has estimated that the maritime traffic on the Baltic Sea will double by 2017. The growth in general cargo and bulk traffic is assumed to triple. For oil transportation, the growth is assumed to be only 10%, but this is probably an underestimation since oil transportation from Russia is expected to grow even more. The average annual growth rate is predicted to be 4.7% for general cargo, container, reefer and RoRo traffic, 2.2% for bulk carrier traffic and 1.4% for oil and gas tankers. The growth in the transportation figures will not directly increase the ship call figures or use of fairways at the same rate because the average size of the cargo vessels will also increase (Wahlström et al., 2006).

Predicting the development of passenger ship traffic is more difficult than forecasting the development of cargo traffic since there are more factors influencing the development. About 300 passenger ferries visit St Petersburg and about 200 passenger ferries visit Helsinki and Tallinn each summer. These vessel numbers are expected to stay at the current level in the coming years' ship traffic forecasts. The passenger traffic on routes from Turku and Helsinki to Stockholm and between Helsinki and Tallinn is not expected to grow any further. It is anticipated that airborne and water-borne nutrient loads will be reduced in the future due to state-of-the-art technology implementation onshore and on-board.

In recent years the public has become more conscious of the state of the Baltic Sea. Even though discharge of ship sewage into the sea is allowed under certain conditions (MARPOL 73/78 Annex IV), public opinion is opposed to it. For example, public pressure made the Tallink and Superfast ferries pump their sewage into the sewer network ashore (Helsingin Sanomat 29.5.2006). It is probable that discharge limits for nitrogen and phosphorus will be set for the on-board sewage treatment systems in sensitive sea areas because a total prohibition on discharging sewage, both treated and untreated, into the Baltic Sea might be difficult to reach. However, research into and development of waste-water purification systems on-board ship are needed before the system's ability to remove nutrients corresponds to the requirements of municipal treatment plants.

Nutrient removal is not impossible to achieve, since Evac's MBR system comes close already. The limit set for the municipal waste-water plant in Viikinmäki (Helsinki) for total phosphorus (0.3 mg/l) almost equals the effluent value that is expected from the Evac MBR process (< 0.5 mg/l). There is no set limit for total nitrogen in the Environmental Permit (City of Helsinki, 2008) but in 2004 the nitrogen concentration in cleaned water in Helsinki was 6 mg/l on average (Helsingin Vesi, 2004). The expected effluent value for nitrogen from the Evac MBR process is 10 mg/l.

11 Conclusions and recommendations (updated)

The shipping companies, shipowners and port authorities consider the environmental aspects to be a significant competitive advantage in the future as competition for market shares in both passenger traffic and cargo transport becomes more stringent. For example, when the inquiry results of this study concerning the waste-water amounts pumped ashore are compared with the inquiry results of the SSPA study in 1994, it can be seen that the passenger ports receive more waste water now than ten years ago. In the Gulf of Finland in particular, the passenger/car ferries have started to pump their waste water ashore as a result of public pressure. However, the cargo ships and the international cruise ships fulfil the MARPOL 73/78 requirements concerning the prevention of pollution by ships in the most economic way by discharging their sewage directly into the sea when it is possible according to the MARPOL 73/78 Annex IV regulations.

The HELCOM recommendation (26/1) regarding the no-special-fee system has made the biggest passenger ports invest in sewer network systems at the pier for receiving the waste waters. In most of the responding ports, the black and grey water holding tanks can be emptied into tank trucks if the ship has ordered depletion. Further investments in the reception facilities may be delayed unless the ships utilize the existing onshore waste-water reception facilities.

In this study, the nutrient load originating from ships' waste waters was compared with the airborne and water-borne nutrient loads. The nutrient load caused by nitrogen and phosphorus from ship sewage is not currently regulated. The standards for ship-borne waste-water quality only concern BOD, total suspended solids and faecal coliforms. Hence the sewage that is discharged directly into the sea increases the nutrient load in the marine environment. The nutrient load calculations were prepared for the whole of the Baltic Sea and the Gulf of Finland. The ship-borne nitrogen load represents approximately 0.04% of the total nitrogen load and the phosphorus load approximately 0.3% of the total phosphorus load for both the Baltic Sea and the Gulf of Finland. In addition, the nutrient load from ships' exhaust gases corresponds to 6% of the total atmospheric deposition of nitrogen in the Baltic Sea.

In the ECC study, the calculations were performed with lower nutrient load factors and passenger numbers. The results indicated that the nutrient loads from cruise ships were 0.007% for nitrogen and 0.052% for phosphorus from the total nutrient load. The ECC study suggests that the values used by VTT were too high.

When comparing nitrogen and phosphorus loads from four coastal cities in Finland with ships' waste-water releases into the Gulf of Finland it can be concluded that the annual nitrogen load from ships represents a much lower amount while phosphorus represents about the same load as in the coastal cities.

Although different background data for the calculations were available, compared with the references, the results appear to be consistent with other studies. The results indicate that the main nutrient load into the Baltic Sea derives from water-borne inputs and atmospheric deposition. On the basis of the calculations and references, it can be concluded that the nutrient load originating from ships is rather small but not negligible due to the sensitivity of the Baltic Sea marine environment. The nutrient load is concentrated along shipping routes, and immediately available for uptake by, e.g., blue–green algae, adding to the severe eutrophication of the Baltic Sea.

In addition to the ship-borne nutrient load, waste-water discharges from pleasure craft may have a local effect on archipelago areas and near coastlines. Since pleasure craft were not included in the study, the effect of their nutrient load should also be estimated if the total nutrient load from maritime transport needs to be defined.

The vulnerable nature of the Baltic Sea area and the ever-increasing eutrophication is forcing a reduction in the nutrient load into the sea. The nutrient load from ships is much easier to reduce, when compared with the atmospheric emissions or nutrient inputs from diffuse sources such as agriculture, by ordering ships to discharge their sewage into the sewer network ashore or by installing purification systems on-board. In the future, it is likely that limits will be set for the concentration of nitrogen and phosphorus in ships' waste waters to be discharged. It is also possible that the growing environmental awareness among customers and shipowners, and technological innovations in advanced on-board waste-water purification systems, together with public concern, may also create voluntary actions beyond the requirements

The purpose of this updated study was to provide background information for the *ad hoc* HELCOM Correspondence Group regarding the possible designation of the Baltic Sea as a special area where more stringent regulations on discharges of sewage from ships would be applied. The main task of the Group is to estimate the effect of the new proposals for new provisions in MARPOL Annex IV on the nutrient load of the Baltic Sea.

The intention was to determine the current situation of the waste-water reception facilities and their usage in the Baltic ports. Also, the availability of on-board sewage treatment plants capable of reducing discharges of nitrogen and phosphorus was investigated. The means used in the investigation were inquiries made by the *ad hoc* HELCOM Correspondence Group and the authors of this report from VTT. The Correspondence Group members approached the ports in their own countries. The availability of treatment plants was studied by sending an inquiry to well-known suppliers of different on-board waste-water purification systems. In the inquiry, the suppliers were asked to provide a cost estimate of on-board waste-water treatment plants for the case study ship.

Information about PRFs, their usage and problems regarding PRFs was received only from a few countries from the Baltic Sea area. Likewise, the response rate to the supplier inquiry was rather poor; only one supplier gave an extensive quotation containing the sought data on the target level of nutrients as well as the estimated costs of the treatment system. As the removal of nutrients is not yet required, the solutions are scarce. It seems that a solution to the problem is possible, though not necessarily cost-effective or widely available yet. Thus further improvement of waste-water purification systems on-board ship is still needed. The effluent values in the existing on-board system are already near those achieved in municipal waste-water treatment plants but the system is rather expensive to install as a retrofit.

Discharge of sewage into PRFs may not be a big problem, and more information was sought concerning the ability of big passenger ships to store all sewage in their tanks while sailing in the Baltic Sea area, if it would be required that all sewage should be discharged into PRFs in the Baltic Sea ports. The CLIA and the ECC offered valuable information and according to them there are several things to be taken into account when considering the storage of all sewage on-board. To provide additional tankage for sewage would require that an equal amount of space be removed from another function on-board. The CLIA is also anxious that storage of treated black water is corrosive and can adversely affect ship structure, integrity and stability, potentially leading to safety concerns. Additionally, the CLIA and the ECC have serious doubts concerning the reliability and availability of the PRF services. In general, the cruise lines seem to be confident with their on-board treatment systems and take the utilization of PRFs with a grain of salt. Therefore an on-board water treatment system with nutrient removal capability could be a more suitable solution than storing the sewage on-board for discharging at port. The development of the PRFs would require a uniform approach in order to generate solutions that could offer real- world alternatives for on-board treatment.

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Appendices

Inquiry 2008

Inquiry 2008

To whom this may concern,

VTT Technical Research Centre of Finland has a commission from the *ad hoc* HELCOM Correspondence Group, via the Finnish Maritime Administration, to investigate the availability of on-board sewage treatment plants that are capable of reducing discharges of nitrogen and phosphorus.

The history behind this is the debate concerning whether HELCOM should propose to the IMO that Annex IV to the MARPOL 73/78 Convention (Regulations for the prevention of pollution by sewage from ships) be amended in order to designate the Baltic Sea as a Special Area where more stringent regulations on discharges of sewage from ships would be applied.

The aim of this inquiry is to gather information concerning the availability and estimated costs of on-board waste-water treatment plants for the case study ship. The case study ship is a cruiser with a passenger capacity of 2,500 persons and a staff of 800 persons. The waste-water load (black and grey) is estimated to be 185 litres per person per day, and the ship is equipped with a vacuum toilet system. Both black and grey waste waters are to be treated on-board.

Those features are be used when estimating purchase, installation and operation costs for a 10-year period as a turnkey option. The sewage treatment plant needs to be retrofitted at a shipyard. The plant must be capable of reducing the nitrogen (ammonium and total N) and phosphorus (soluble total P) load from the sewage. The reduction rate [%] or target level [mg/l] should be indicated.

In addition, all the views and comments you may have in relation to on-board waste-water treatment plants (e.g. suitable reduction rates for N and P, installations and operations of the plants, cost issues, etc.) are welcome.

The results of this inquiry will be distributed to the HELCOM Correspondence Group in order to support its decision making.

We would appreciate it if you could respond to this inquiry by 9 May 2008.

If you need more information relevant to this inquiry, do not hesitate to contact VTT.

Kind Regards,
Jukka Sassi, Research Engineer, B.Sc. (Eng.)

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