Kymijoen
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STUDY OF GREY WATER SAMPLES FROM CARGO AND PASSENGER SHIPS AND AN ASSESSMENT OF THE IMPACTS OF WASTEWATER ON THE MARINE ENVIRONMENT

Research Report no. 519/2021 by
Water and Environment Association of the River Kymijoki
(Kymijoen vesi ja ympäristö ry)

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ISSN 2670-2185

CONTENTS

APPENDICES

6 August 2021

1 INTRODUCTION

This study of grey water samples from cargo and passenger ships was conducted in cooperation with the Baltic Sea Action Group (BSAG). The report concerns the project “Harmaiden vesien ja ruokajätteen vastuullinen käsittely Itämerellä” (responsible treatment of grey water and food waste in the Baltic Sea) conducted by the foundation and funded by the European Maritime and Fisheries Fund (EMFF) Operational Programme for Finland 2014-2020.

Earlier studies on wastewater from ships has particularly focused on sewage (black water) and on passenger ships. Very little research has been done on grey water, and even that little research is usually based only on data from passenger ships. More information on the sewage generated by cargo ships is needed in order to assess the amount of sewage discharged and its impact on the marine environment. The aim of this report was to gain an understanding of the content in grey water, and to assess the impacts of grey water on the marine environment. In this report the term sewage refers to black water or a mix of black and grey water.

During 2020 and 2021, BSAG has commissioned grey water sampling from nine different cargo ships and two different passenger ships. These grey water samples were used to determine whether there is a difference between vessel types in, for example, grey water nutrient and bacteria concentrations. The concentrations in the grey water samples and the amount of grey water generated on the ships were used to estimate the load from the vessels. The passenger ships taking part in the sampling discharge all their waste, including black and grey water ashore. The samples taken from the passenger ships serve as a comparison to the cargo ships. Samples were taken from cargo ships from both Finnish and foreign shipping companies complying with responsible operating practices.

The report also has a second part, which examines the theoretical load from ships visiting the port of HaminaKotka in 2020. Based on port calls during 2020, the load from the ships and the possible impacts of the ships’ sewage on the marine environment were estimated. To estimate the load, statistics on the port calls, the different types of ships and their size class were used. Based on a survey conducted by BSAG in 2020, information was obtained on, for example, the size of ships’ sewage tanks, their sewage treatment systems and the number of crew members. The survey was conducted in 2020 on ships entering Finnish ports. It was carried out by members of Shipbrokers Finland at 12 Finnish ports. The cargo ships also reported whether they discharged black or grey water into the sea. This information was used as a baseline for this report to estimate the load discharged into the sea.

PART 1

2 BACKGROUND INFORMATION

Grey water is generated from water used during washing and showering and from the kitchen, whilst black water contains wastewater from toilets. Black water contains more nutrients than grey water. The concentrations of the different parameters in grey water vary according to where the grey water originates from. For example, grey water from kitchens contains a particularly large amount of organic matter (HELCOM 2019).

There are different regulations concerning sewage treatment on ships and the discharge of sewage in the Baltic Sea. MARPOL Annex IV contains regulations regarding sewage. According to MARPOL Annex IV, the Baltic Sea is a special area where sewage from passenger ships must be discharged to port reception facilities or treated in the ship's own sewage treatment system before being discharged into the sea (IMO 2021a).

Since 2019, new passenger ships have been prohibited from discharging untreated sewage into the sea in Special Areas, and existing passenger ships were prohibited from doing so on 1 June 2021. From 2023 (1 June 2023), this will also apply to existing passenger ships that sail directly to/from a port outside the Baltic Sea Special Area or to/from a port east of longitude 28°10' E within the Baltic Sea Special Area, and do not call at other ports within the Special Area (St Petersburg area – North Sea) (IMO 2021a).

Untreated sewage from ships cannot, be discharged into the sea if the ship is closer than 12 nautical miles from the nearest land (approx. 22 km). Sewage treated in accordance with the regulations can be discharged 3 nautical miles from the nearest land (approx. 5.5 km). These regulations concern cargo ships (IMO 2021a).

The regulations do not concern grey water, which can be discharged into the sea without restrictions, even in the Baltic Sea. On some ships, black and grey water mix before being discharged. In such cases, the same rules apply to their discharge as for black water (HELCOM 2019). The new regulations concerning passenger ships only apply to black water. Even after the new regulations come into force, passenger ships can discharge grey water and ground food waste into the Baltic Sea. In the same way, cargo ships can discharge ground food waste into the sea, either as it is or mixed with grey water. MARPOL Annex V prohibits the discharge of non-ground food waste into the Baltic Sea. Ground food waste may be discharged into the sea at a distance of 12 nautical miles or more from the nearest land (IMO 2021b). This report focuses on grey and black water from ships.

3 SAMPLING

Samples were taken from ships between the beginning of October 2020 and the end of April 2021. A total of 42 samples were taken, 30 of which were from cargo ships and 12 from passenger ships (Table 1). The names of the ships are not reported. The samples were taken from ships which sail under both Finnish and foreign flags. The report involved cargo ships with separate tanks for grey and black water. The passenger ships did not have separate tanks for grey and black water, so the samples were taken directly from the grey water pipes. The grey water samples from the cargo and passenger ships are therefore not directly comparable. The samples were taken at three ports: Helsinki, Porvoo and HaminaKotka. Due to the Covid-19 pandemic, visits on board the ships were restricted so the sampling was done by the crew members. The sampling instructions were sent to the ship captains and chief engineers (Annex 1). The instructions covered two sampling methods, so that the samples could be taken according to where the grey water tank on the ship was located.

Table 1. Information about the ships included in the report.

CARGO SHIPS

ship	dwt	type of ship	volume of grey water tank (m3)	number of crew	amount of samples
SHIP1	2 300	bulk carrier	2,7	5	5
SHIP4*	7 500	RoPax	10,3	33	5
SHIP5	15 000	tanker	24,8	16	5
SHIP6	15 000	tanker	24,5	16	2
SHIP7	20 000	bulk carrier	41,2	15	4
SHIP8	40 000	container	47,9	22	3
SHIP9	40 000	container	47,9	22	2
SHIP10	40 000	container	47,9	22	3
SHIP11	40 000	container	47,9	22	1

PASSENGER SHIPS

ship	dwt	type of ship	number of crew	number of passengers		amount of samples
SHIP2	3500	RoPax	130	7.1.2021	186	7
				11.1.2021	256	
				13.1.2021	161	
				18.1.2021	256	
				20.1.2021	159	
				25.1.2021	unknown	
				11.2.2021	119	
SHIP3	6000	RoPax	130	7.1.2021	224	5
				18.1.2021	615	
				20.1.2021	230	
				25.1.2021	unknown	
				11.2.2021	115	

dwt= d*ead weight tonnage*
RoPax= *roll on/roll off and passenger ship*

*SHIP4 takes on passengers, but he numer of passangers is not known.

Based on the schedules of the ships, BSAG coordinated the sampling in advance with the person responsible for sampling, the person responsible for transporting the sample, and the laboratory. It was important to ensure that the sample was taken only when there was enough grey water in the ship's tank. A precise time was agreed on for taking the sample and transporting it to the laboratory, so that the interval between sampling and analysis was as short as possible. Some of the samples were rejected because they had been taken too early before the ships' arrival in port, or because the samples had waited too long in port before being taken to the laboratory.

The following analyses were conducted on the samples:

BOD (biochemical oxygen demand BOD5 or BOD5(ATU))
BOD5 and BOD5(ATU) are not directly comparable so the results were handled separately.
COD (chemical oxygen demand COD_{Cr})
suspended solids (GF/A)
chloride
pH
total nitrogen
total phosphorus

BSAG commissioned the analysis of all samples at FINAS-accredited Kymen Ympäristölaboratorio Oy and Metropolilab Oy.

4 RESULTS

4.1 THE RESULTS FROM THE GREY WATER SAMPLES

The laboratory results of the ships' grey water samples are presented in full in Appendix 2. The results describe the concentrations of different parameters in the grey water. Conclusions cannot be drawn merely on the basis of the concentrations of the different parameters. The load is primarily affected by the amount of water discharged.

In general, the concentrations varied a lot between samples when all the grey water samples were taken in to account. COD and BOD concentrations varied particularly much. COD (chemical oxygen demand) indicates the consumption of oxygen caused by the organic matter in the water through chemical reactions. BOD (biochemical oxygen demand) indicates the biological consumption of oxygen caused by the organic matter in the water (Oravainen 1999). The pH value of the ships' grey water samples ranged from very alkaline to acidic (Appendix 3).

The concentrations of the different parameters in the grey water of the cargo ships were generally greater than in the passenger ships. The samples from the cargo ships were taken from grey water tanks, whilst the passenger ships had no separate grey water tank so the samples were taken directly from the grey water pipes. Because of this, the laboratory results of the cargo ships and passenger ships are not directly comparable. There was less variation in concentrations of the different parameters in the grey water samples from passenger ships compared to the samples from cargo ships. For example, in the cargo ship samples the pH value varied between 5.8 and 10.6 and, in the passenger ship samples, between 6.2 and 7.3. The average BOD, COD and suspended solids concentrations in the cargo ship samples were almost double those of the passenger ship samples. The average nutrient concentrations were also greater in the cargo ship grey water than in that of the passenger ships (Figure 1–2).

The chloride concentrations were particularly high in the cargo ship grey water samples. According to a study by HELCOM, the average chloride concentration in passenger ship grey water was 125 mg/l (HELCOM 2019). According to the results, the average chloride concentration in passenger ships was 24 mg/l and, for cargo ships, 189 mg/l. The greatest chloride content in a single sample was 850 mg/l. Such a large concentration indicates that a sanitising substance containing either chlorine or chloride was added to the grey water tank.

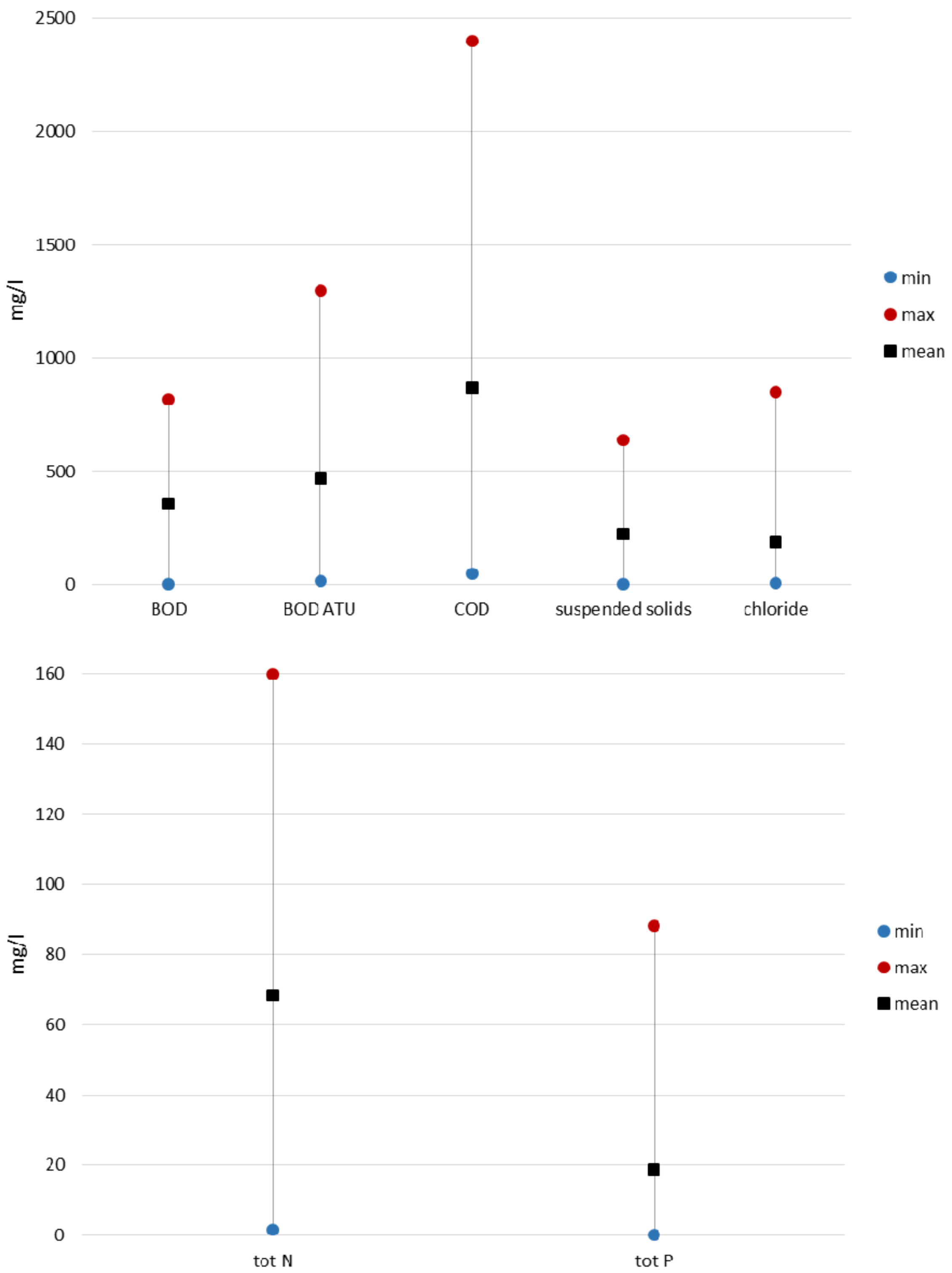
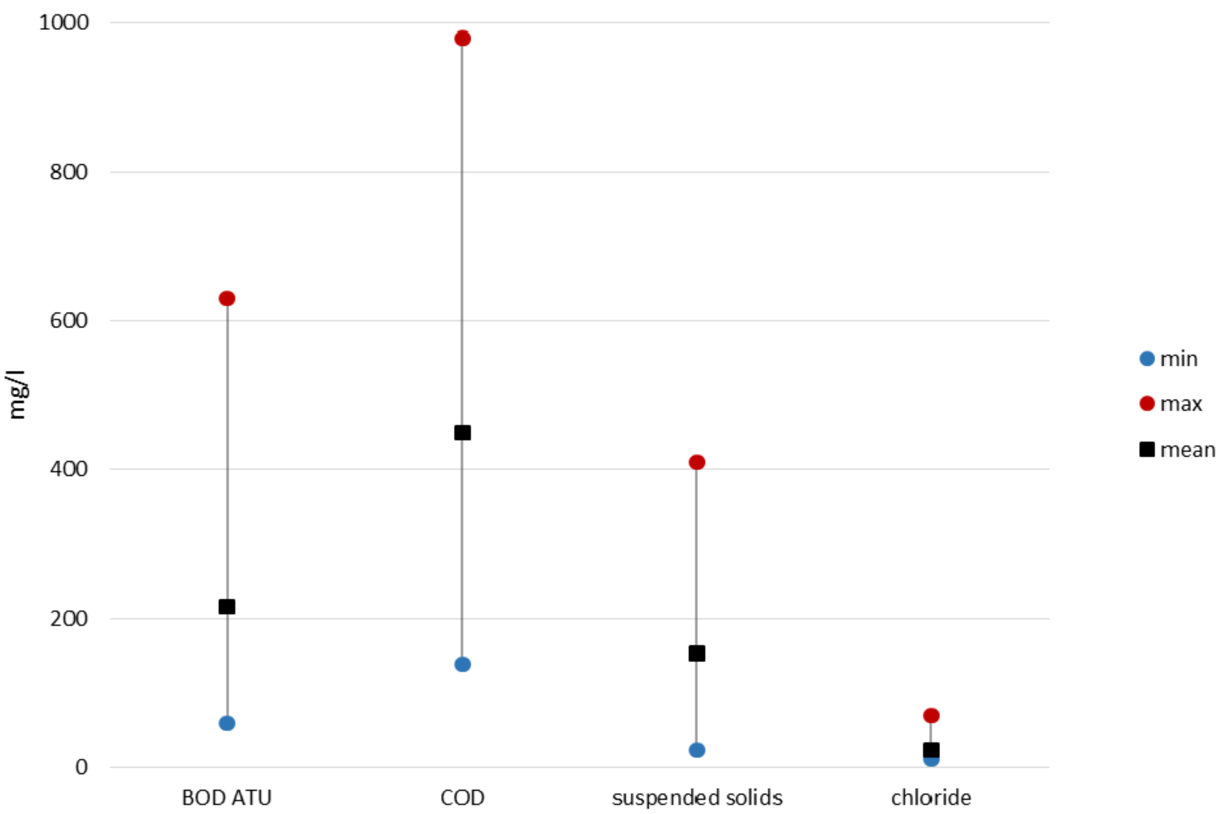


Figure 1. BOD, BOD(ATU), COD, suspended solids, chloride and nutrient concentrations in cargo ship grey water samples. Average-, minimum- and maximum values of concentrations.



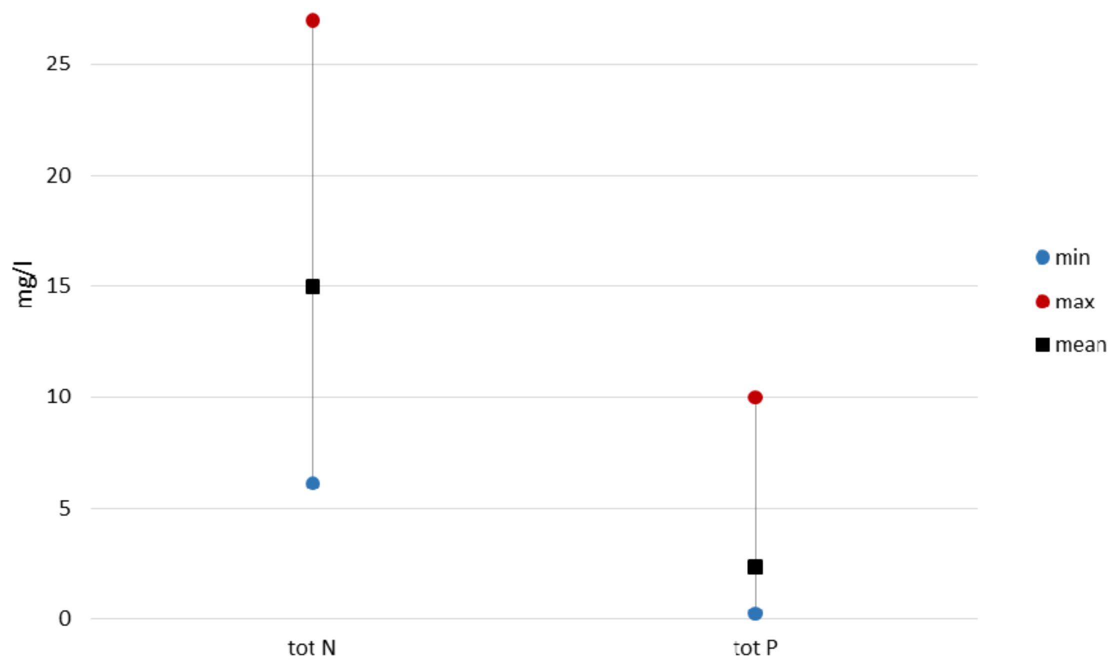


Figure 2. BOD(ATU), COD, suspended solids, chloride and nutrient concentrations in passenger ship grey water samples. Average-, minimum- and maximum values of concentrations.

The bacterial concentrations in the samples were high, both for the cargo ships and passenger ships samples. The bacterial concentrations also varied greatly between samples. The samples were analysed for the presence of heat-tolerant coliform bacteria. Heat-tolerant coliform bacteria indicate the hygienic quality of the water. The average concentrations of bacteria were greater in the passenger ship grey water than in that of the cargo ships. The greatest bacterial concentration in a single sample also came from a passenger ship. One cargo ship sample contained none of the analysed bacteria at all (Figure 3).

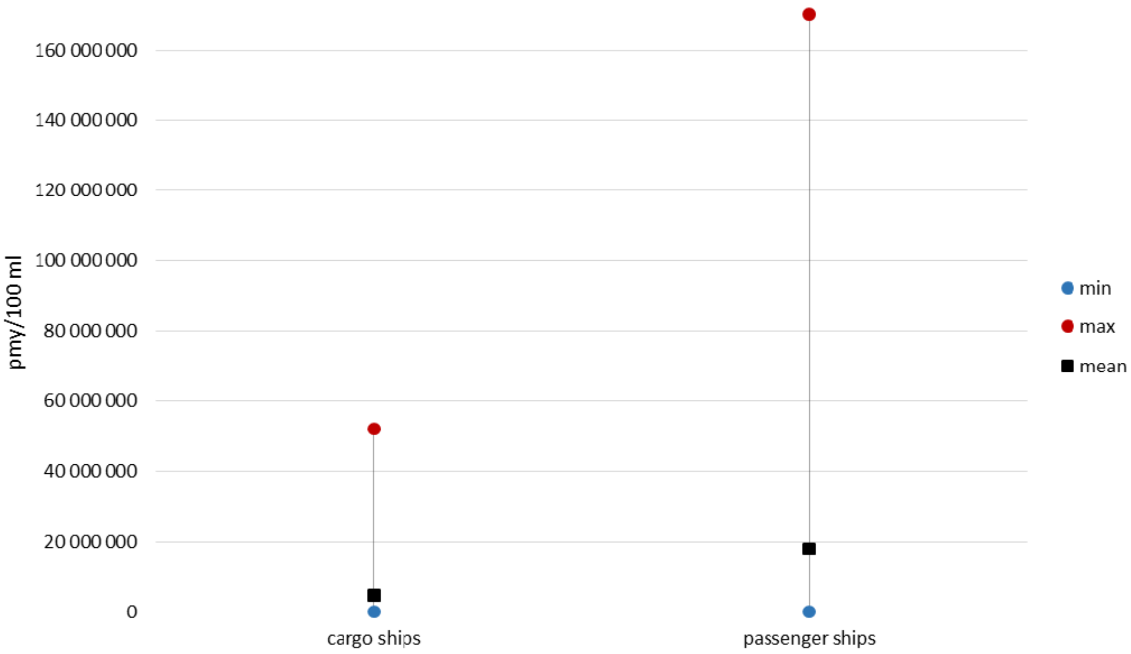


Figure 3. The average concentrations, minimum values and maximum values of heat-tolerant coliform bacteria in the grey water of the cargo and passenger ships.

4.2 GREY WATER LOAD

The grey water load from cargo ships and passenger ships was estimated based on the grey water sample results, the numbers of crew and the grey water generated per person. Based on the literature, it was estimated that approx. 130 l/person/day grey water is generated (Furstenberg et al. 2009). The average amount of grey water generated per person on the different types of ship were used in the load calculations (Furstenberg at al. 2009). The load indicates how much (in kg) suspended solids, for example, is discharged from the ship into the sea along with grey water per day. The estimated load of the ships is their theoretical load; for example, the passenger ships in the report discharge their sewage in port.

The passenger ship load was greater than that of the cargo ships. For example, COD and suspended solids load in the passenger ships was almost 10 times greater than that of the cargo ships (Tables 2 and 3).

Table 2. Average grey water load and minimum- and maximum grey water load values in the cargo ships.

	BOD 5 kg/d	BOD5 ATUkg/d	COD kg/d	suspended solids kg/d	chloride kg/d	tot. N kg/d	tot. P kg/d
mean	0,8	0,9	2,4	0,6	0,4	0,2	0,05
min	0,1	0,4	0,8	0,0	0,1	0,0	0,00
max	1,3	2,0	6,6	2,4	1,2	0,3	0,24

Table 3. Average grey water load and minimum- and maximum grey water load values in the passenger ships.

	BOD5 ATU kg/d	COD kg/d	suspended solids kg/d	chloride kg/d	tot. N kg/d	tot. P kg/d
mean	10,4	21,1	6,4	1,2	0,7	0,2
min	2,0	5,3	0,9	0,3	0,1	0,0
max	31,0	59,1	19,2	3,3	1,7	1,0

4.2.1 Impact of passenger and crew numbers on the load

The number of crew and passengers on the ships affected the amount of grey water generated and also the load. The passenger ships had the highest number of people on board, and this was also evident in the load figures (Tables 2 and 3). The passenger ships had crews comprised of 130 people and the number of passengers varied between 100 and 700. The highest number of passengers occurred on ship 3 on 18 January 2021 (Table 1). The samples were taken during the Covid-19 pandemic, so the numbers of passengers were probably lower than normal. The BOD, COD, nitrogen and phosphorus loads of the passenger ships were greatest on ship 3 on 18 January 2021, when the ship carried the most passengers (615). The suspended solids and chloride load of the passenger ships was, however, greatest on ship 3 on 20 January 2021 (Appendix 4). On that date, the number of passengers was 230 (Table 1).

For the cargo ships, the average loads for phosphorus, nitrogen and chloride were greatest on ship 10 (Appendix 4). Ship 10 had a crew of 22 (Table 1). The average suspended solids load was greatest on ship 9, the average COD load greatest on ship 11 and the average BOD load on ship 4 (Appendix 4). On ships 9 and 11, the crews comprised of 22 people and, on ship 4 the number of crew was 33 (Table 1). On the passenger ships, the number of people on board was considerably greater than on the cargo ships, and the load was greatest on the ships that had the highest number of passengers and/or crew. The size of the load is affected by water consumption, which varies according to the number of passengers and crew. The amount of grey water used in the load calculations does not completely match the actual water consumption on the ships.

4.2.2 Comparison to the load of sewage treatment plants

The load of the ships can be compared to that of sewage treatment plants in order to obtain a better picture of the load from the ships. The sewage treatment plants presented in this report are Finnish plants that discharge treated wastewater into the Baltic Sea. The BOD7(ATU) concentration of the sewage treatment plants and the BOD5(ATU)/BOD5 concentration of the ships' grey water samples are not directly comparable. The sewage treatment plants treat an enormous amount of sewage every day, and modern plants are very efficient. The daily load of the sewage treatment plants was greater than the grey water load of the ships. It must be taken into account, that the sewage treatment plants handle both grey and black water together. The average phosphorus load at the sewage treatment plant (plant 2) was almost 10 times that of the passenger ships (Tables 2–4). There are multiple ships in traffic simultaneously on the Baltic Sea and they produce a considerably greater load than individual vessels.

Table 4. Average load information from two sewage treatment plants in 2019 and 2020.

Wastewater treatment plant 1 Load 2020		**Wastewater treatment plant 2 Load 2019**	
	kg/d		**kg/d**
BOD7atu	178	**BOD7atu**	32
P	6	**P**	2
N	210	**N**	147
suspended solids	180	**suspended solids**	33
CODcr	1 606	**CODcr**	333
mean flow	31 332 m3/d	mean flow	12 221 m3/d

5 SUMMARY

The average concentrations of the different parameters in grey water from the passenger ships were generally lower than in that from the cargo ships. The average bacterial concentration was the only parameter greater on the passenger ships than on the cargo ships. There was great variation between samples in concentration of the different parameters. Concentrations were affected, for example, by the water use in different activities on board and at what time the sample was taken. The passenger ships did not have a separate grey water tank, so the samples were taken directly from the grey water pipes, whereas on the cargo ships the samples were taken from the grey water tank. The grey water samples from the cargo and passenger ships are therefore not directly comparable. The report was conducted during the Covid-19 pandemic, so the samples were taken by the crew members. It is often a requirement in water quality monitoring that a certified sampler conducts the sampling, but that was not possible in this case.

The Covid-19 pandemic also affected the numbers of passengers on the passenger ships. The numbers of passengers were presumably lower during the sampling period compared to previous years due to the pandemic. The estimated load of the ships is based on water consumption, and it is particularly affected by the number of people on board. On the passenger ships, the number of people on board, and therefore also the water consumption, were greater than on the cargo ships, and the load was also generally greater on the passenger ships than the cargo ships. Future studies could try to consider the actual water consumption on the ships, so that the load calculations are based on actual amounts of grey water.

PART 2

6 THE LOAD OF THE CARGO SHIPS

The impacts on the marine environment of the sewage from the ships were estimated based on ship load. The load was estimated for cargo ships that had visited the port of HaminaKotka during 2020. The number of ships in the area of Kotka and Hamina was calculated by using information on port calls. BSAG assembled background data on the ships based on information received from Traficom (Finnish Transport and Communications Agency).

Based on the port calls in 2020, the vessels could be divided into four groups: tankers, bulk carriers, container ships and RoRo vessels (roll- on/roll-off). These four ship types accounted for 97% of the port calls in port of HaminaKotka in 2020 (Table 5).

Table 5. Background information on ships visiting the port of HaminaKotka in 2020. Source: Traficom. Crew numbers and the vessel sizes are average values based on Traficom's statistics and the results from the BSAG survey.

Type of ship	Number of crew	Ship size, dwt	Port calls in 2020	Percentage of all port calls, %
tanker	17	10 230	505	22
bulk carrier	10	8 710	919	39
container	19	22 777	463	20
RoRo-vessels	17	14 154	381	16

Port calls in 2020, Port of HaminaKotka

The grey water load estimations were based on the number of crew, the amount of grey water generated and information on concentrations of different parameters in the grey water. Information on the concentrations in the grey water was obtained from the first part of the report and, based on the literature, it was estimated that the generation of grey water is approx. 130 l/person/day (Furstenberg et al. 2009). Black water load estimations were based on the number of crew and the black water load values. The load values indicate the nutrient and BOD content in black water per person per day; total phosphorus 1.8 g/person/day, total nitrogen 13 g/person/day and BOD7 20 g/person/day (website of Finland's Environmental Administration 2019). The load values are also used in Finnish Government Decree 157/2017. The load value for BOD7 was converted to BOD5 according to available instructions from HELCOM (HELCOM 2011).

The cargo ship load (kg/day) estimation was based on water consumption, and the total load was based on the port calls. The load was estimated separately for grey and black water. During 2020, a total of 4,300 m^3 of grey water was generated on the ships, and the total number of crew members based on visits to port was 33,049. This number of people is equivalent to the populations of, for example, Nokia or Savonlinna (Association of Finnish Municipalities 2021). The BOD load of grey water was considerably greater than the black water BOD load, whilst the nitrogen black water load was greater than the grey water nitrogen load (Table 6–7). The large BOD grey water load is partly the result of the large amount of organic matter in kitchen water. Grey water discharges are not regulated under MARPOL, although their load can be even higher than for black water, especially for BOD and COD (HELCOM 2019), which is also the case in this report.

Table 6. The cargo ship load (kg/day) based on number of crew and water consumption. The load was calculated by ship type, and the calculations take into account the number of crew per ship. The load shown in the table is the total load for the different types of ship.

	BOD kg/d	COD kg/d	suspended solids kg/d	tot. N kg/d	tot. P kg/d
Grey water load	3,39	7,13	1,83	0,56	0,15
Black water load	1,10			0,82	0,11
Total	4,49			1,38	0,27

Table 7. The total load for the cargo ships (kg/yr.) in 2020 based on the port calls in port of HaminaKotka. The load was calculated by multiplying the number of crew with the port calls in 2020, so the load is based on water consumption for the whole year.

	BOD kg/yr.	COD kg/yr.	suspended solids kg/yr.	tot. N kg/yr.	tot. P kg/yr.
Grey water	1 780	3 742	961	294	80
Black water	575			430	59
Total	2 355			724	139

The next load estimations took into account that some of the ships discharge their sewage on land and some have a sewage treatment system (Table 8). The load calculations assumed that 50% of the ships discharge their sewage untreated into the sea, 15% treat their sewage before discharging (70% of nitrogen and 80% of phosphorus removed) and 35% do not discharge their sewage into the sea. The assumptions are based on the results of the BSAG survey. It was also assumed that all black and grey water generated is discharged in a one-off release.

The total load of the ships decreased when the different sewage treatment methods of the ships were taken into account (Table 7 and 8). The requirements of the ships' sewage treatment systems were only taken into account for the nitrogen and phosphorus loads. The part-two cargo ship load was also smaller than the load for the sewage treatment plants (see section 4.2.2). The load for all the maritime traffic on the Baltic Sea is of course considerably greater than the load in this report.

Table 8. The total load of black and grey water from cargo ships in 2020 based on visits to the port of HaminaKotka. The different sewage treatment alternatives are taken into account in the load calculations.

	BOD kg/yr.	**kok. N kg/yr.**	**kok. P kg/yr.**
Total	1531	395	74

7 ASSESSMENT OF THE IMPACTS OF SEWAGE ON THE MARINE ENVIRONMENT

The Baltic Sea is quite shallow and the water replacement is extremely slow. There is dense settlement around the Baltic Sea and plenty of nutrients enter the sea with river water, sewage and run-off. The Baltic Sea suffers from eutrophication and also from internal load. Signs of the eutrophication include reduced visibility and excessive growth of algae and aquatic plants. Nitrogen and phosphorus in particular are eutrophying the Baltic Sea (HELCOM 2010 and HELCOM 2018). The relationship between different nutrients in the sea also regulate primary production. The limiting nutrient is the nutrient that runs out first, and it limits the primary production. In other words, when an essential nutrient runs out, algae growth is inhibited. In the Baltic Sea, the limiting nutrient can change from nitrogen to phosphorus, for example according to the seasons (Itämeri.fi website 2021). The availability of nutrients regulates algae growth, particularly during the growing season, because then light and temperature conditions are favourable. Increased primary production increases the decomposition occurring on the seabed, and increased decomposition consumes oxygen, as a result of which a lack of oxygen may occur in the water close to the seabed. In addition to the nutrients, organic matter also increases the problems caused by eutrophication. As a result of eutrophication, the species composition of an area may change and thus also the entire food web (HELCOM 2010 and HELCOM 2018).

The area off Hamina and Kotka is in the focus when assessing the impacts of ship sewage on the marine environment. In this report, it is assumed that ship sewage is discharged in a single release 12 nautical miles from the nearest coast. This is the nearest point at which ships may discharge untreated sewage according to the MARPOL Annex IV. This report assumes that the ships discharge both untreated and treated sewage 12 nautical miles from the nearest coast.

The outer limit of the Finnish territorial sea is located 12 nautical miles from the nearest land, so the intersection of the Hamina-Kotka entrance waterway and the outer limit of Finland's territorial sea is the closest discharge point to the port. The depth at the discharge point varies between approx. 10 and 40 metres. There are a few islets near the discharge point, around the islets the water is shallower. Further out, the depth is generally more than 50 m (Figure 4, Appendix 5). The ecological status of the Hamina and Kotka coastal waters was assessed as moderate in the 3rd planning period of water management (Finland's Environmental Administration, Hertta system). Based on the average chlorophyll concentration in the 2020 growing season, the sea area belongs to the category eutrophic in the eutrophication classification of coastal waters (Nakari and Anttila-Huhtinen 2021, Pitkänen 1994).

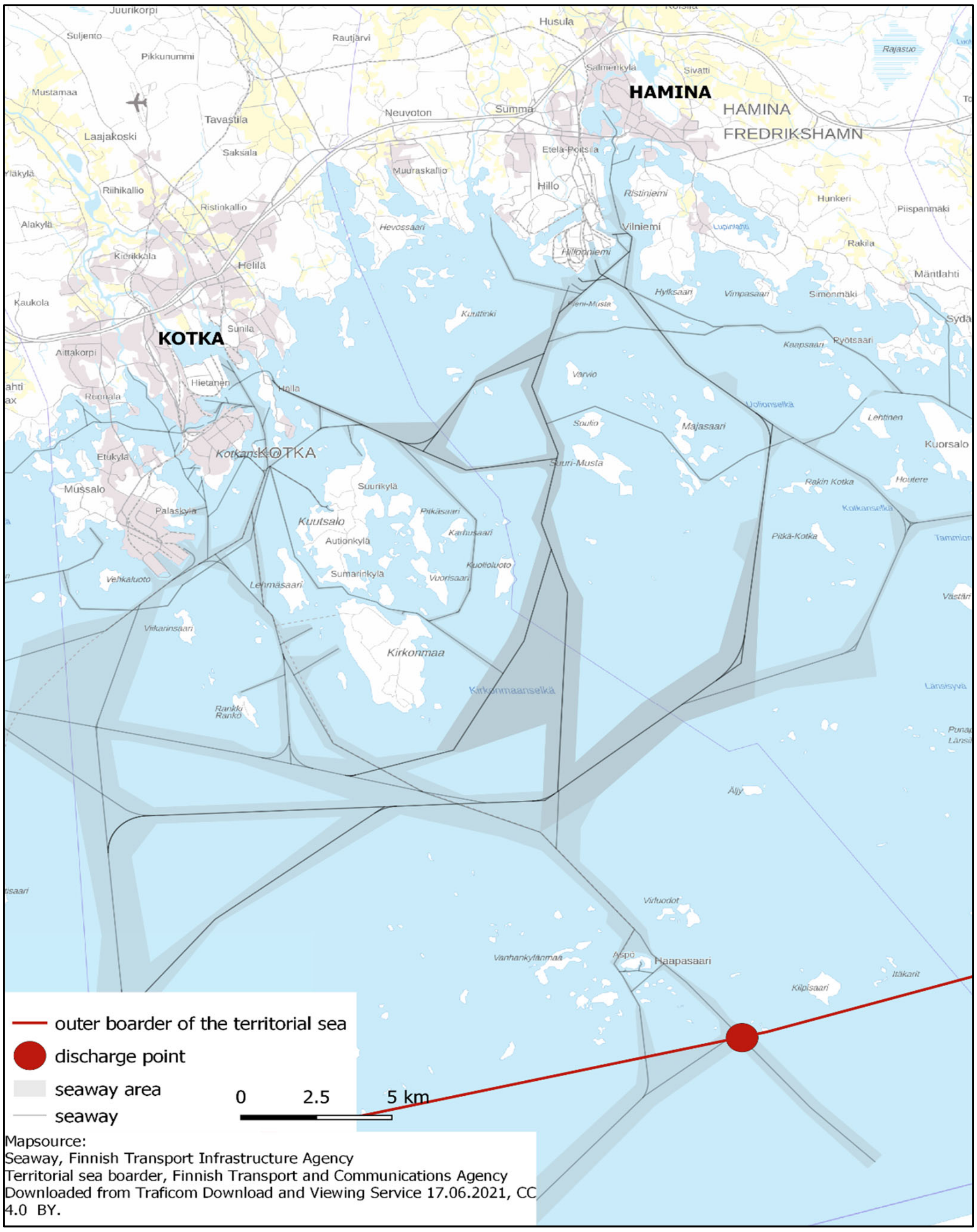


Figure 4. Map of assumed discharge location. According to MARPOL Annex IV, the discharge point for untreated black water should be at least 12 nautical miles from the nearest land.

Sewage has a eutrophying effect, and the nutrients in sewage increase algae growth. Increased nutrient load, particularly when the water is warm, can also increase the production of cyanobacteria. This has a direct impact on the recreational use of an area. Sewage also contains a large amount of organic matter. The organic matter in sewage consumes a lot of oxygen, which can cause oxygen deficiency at deeper depths where the water exchange is slow (HELCOM 2018). In the 2020 growing season, the waters off Kotka and Hamina were generally co-limited, with nitrogen and phosphorus both being limiting nutrients. During the 2020 growing season nitrogen was at times the factor limiting growth further out at sea (Nakari and Anttila-Huhtinen 2021). The nitrogen load caused by ship sewage can in cases like this increase algae production and locally promote eutrophication. It is estimated that the nutrient load from ships is 0.3% of the total phosphorus load entering the Baltic Sea and 1.25-3.3% of the total nitrogen load (Wilewska-Bien et al. 2019, Raudsepp et al. 2019). Most of the Baltic Sea’s nitrogen and phosphorus load comes from rivers (HELCOM 2018).

The total phosphorus load of the Pyhtää−Kotka−Hamina coastal area was approx. 690 kg/day, and the nitrogen load approx. 18,800 kg/day in 2020. In these loads, the load from rivers descending into the area and the point source pollution on the coast from Pyhtää to Hamina were taken into account (Nakari and Anttila-Huhtinen 2021). The portion of the cargo ships’ load was 0.04% for phosphorus and 0.01% for nitrogen of the total load entering the Pyhtää−Kotka−Hamina area. In the publication Nakari and Anttila-Huhtinen 2021, load sources from a wider area than the Hamina and Kotka coastal area were taken into account. The total load from the ships was small compared to the load from point source pollution in the Hamina and Kotka coastal area (Nakari and Anttila-Huhtinen 2021). The load from the cargo ships can be temporarily and locally notable. This report, however, took into account ships and their load in only one marine area. There are multiple ships in traffic simultaneously on the Baltic Sea and they produce a considerably greater load than individual vessels.

The water turnover time and the currents in an area affects the spreading and mixing of sewage. The Finnish coastline is generally rugged, which affects the water turnover time (Finnish Environment Institute 2004). Currents in the Hamina and Kotka coastal area depend mainly on wind and stratification conditions, and during summer stratification, the direction of currents generally follows the prevailing wind direction (Nakari and Anttila-Huhtinen 2021). Sewage spreads and mixes with seawater in a different way depending on the discharge point and the prevailing conditions. Ships discharge their sewage either as one-off discharge or continuously during their voyage, and the mode of discharge affects how the sewage is mixed and spread with seawater.

According to the part-one results of the report, the grey water from the ships contained a great deal of bacteria. Bacteria indicate the hygienic quality of the water. The survival of bacteria in natural waters largely depends on external factors such as water temperature, UV radiation, the amount of oxygen, pH and the amount of nutrients. Intestinal pathogenic microbes cannot usually multiply without a host animal. In water, however, they can survive for long periods if the conditions are favourable (Hokajärvi 2008). Different types of bacteria have their own requirements on conditions in order to survive. The temperature of Finnish natural waters is quite low for most of the year so intestinal pathogenic microbes do not usually multiply in natural waters (Hokajärvi 2008). Intestinal microbes do, however, survive in natural waters. Bacteria and other pathogens can be harmed by UV radiation. In Finnish conditions, UV radiation particularly affects the survival of bacteria in the summer when the radiation is strong (Hokajärvi 2008). The bacteria from ship sewage particularly affect the recreational use of an area. Invertebrate organisms living in natural waters use microbes in the water as food (Hokajärvi 2008), so the bacteria and other microbes from the sewage end up in the sea’s food web.

8 SUMMARY

The total estimated grey water discharges from the cargo ships that visited the port of HaminaKotka during 2020 amounted to approximately 4,300 m3/year. The BOD load of grey water was considerably greater than the BOD load of black water. However, the nitrogen load in black water was slightly greater than in grey water. The portion of the load from cargo ships was 0.01 % for phosphorus and 0.04 % for nitrogen of the total load entering the Pyhtää−Kotka−Hamina coastal area. The total load from the ships was small compared to the load from point source pollution in the coastal area of Hamina and Kotka. The load from ships can be temporarily and locally notable. The nutrient load from ships can more easily be reduced compared to, for example, the riverine nutrient input. This report took into account only ships and their load in one area. The combined load of all the ships sailing the Baltic Sea is significantly greater than the load of ships from a single area.

The eutrophying effect of sewage can be seen, for example, in increased algae production. And organic matter in sewage can cause increased consumption of oxygen and even oxygen deficiency. The water turnover rate and currents in the discharge area affect the spreading and mixing of sewage. Sewage also contains a large number of bacteria, which affects the hygienic quality of the water. Intestinal pathogenic microbes can survive even in natural waters if conditions are favourable.

Further studies are needed to obtain more information about the content in ship sewage. More samples of sewage are needed from ships, both from black and grey water. More information about the actual water consumption on ships is also important, so that the load from ships can be estimated more precisely. More information about the efficiency of sewage treatment and its results on ships is also needed. The discharge of grey water from ships is not restricted, and because of this, it would be important to study and obtain more information about grey water and the grey water load.

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Sampling instruction for grey water

In principal ships have two (2) types of holding tanks for ship grey water
Type 1: grey water storage tank located in ships double bottom
Type 2: gray water tank located inside engine room on one of the engine platform deck, or similar

Sampling rules from Type 1 gray water tank
Rule #1 Grey water tank should not be discharged prior to sampling.
Rule #2 Opening of grey water manhole cover while tank is partially full or almost full. Take tank sample using clean jug that can be submerged 30-50cm below liquid surface. Alternatively, for collecting sample from tank, use pipe with a non-return ball valve as shown in the picture below to pull sample from the tank. The grey water sample can be filled directly from the jug or the pipe to sample bottles



Sampling from Type 2 gray water tank
Rule #1 Grey water tank should not be discharged prior to sampling.
Rule #2 Opening of manhole cover while tank is partially full or almost full is most likely not possible. Therefore take sample trough a separate tank bulkhead valve. Alternatively, if tank is fitted with manual tank level gauging as shown in the picture below, draw sample from tank level gauging valve. Before taking the sample, drain (~5 liters) of gray water to bucket or jug and empty to bilge. The grey water sample can be filled to sampling bottles or via a clean jug. Jug should be rinsed with gray water to ensure there is no contaminant on the jug.

Bottles for each sample are, 2x 1.0 liter plastic bottle and one (1) small bacteria sample bottle (blue cap). Bacteria bottle is sterile so the opening of the bottle and the inside of the cap should not be touched and keep away from any other contact than the gray water itself. Some air gap should be left in the sample bottles. Filling until the bottle ”shoulder” is good.

After collection of samples (3pcs) fill in the document form which is supplied with the bottles. Following parts of the sample form should be filled:

- ship name
- date
- person responsible for sampling
- point where the samples are taken (name of tank).

The results from the grey water samples.

Ship	Type of ship	Sampling date	BOD5 mg/l	BOD5 ATU mg/l	COD(Cr) mg/l	Suspended solids mg/l	Chloride mg/l	pH	Tot. N mg/l	Tot. P mg/l	Heat-tolerant coliform bacteria pmy/100ml	Laboratory
SHIP1	cargo	4.11.2020		1300	2400	570	120	5,8	100	14	3 300 000	Metropolilab
SHIP1	cargo	11.11.2020		400	760	74	100	7,0	27	3,4	160 000	Metropolilab
SHIP1	cargo	12.10.2020		870	1600	450	150	6,8	65	7,5	11 000 000	Metropolilab
SHIP1	cargo	23.10.2020		570	1200	260	130	6,8	35	4,9	12 000 000	Metropolilab
SHIP1	cargo	28.10.2020		390	840	180	110	10,1	41	4,4	180 000	Metropolilab
SHIP2	passanger	7.1.2021		230	670	250	20	7,1	17	3,8	160 000	Metropolilab
SHIP2	passanger	11.1.2021		59	220	85	12	7,3	12	1,2	1 000	Metropolilab
SHIP2	passanger	11.2.2021		92	200	370	17	7,0	13	0,42	16 000	Metropolilab
SHIP2	passanger	13.1.2021		92	250	72	19	6,9	12	0,54	11 000	Metropolilab
SHIP2	passanger	18.1.2021		130	400	210	14	6,7	15	1,7	270 000	Metropolilab
SHIP2	passanger	20.1.2021		58	140	23	13	7,0	13	0,24	18 000	Metropolilab
SHIP2	passanger	25.1.2021		140	320	53	15	6,9	6,1	0,39	2 000	Metropolilab
SHIP3	passanger	7.1.2021		250	520	83	19	6,7	27	3,2	3 400 000	Metropolilab
SHIP3	passanger	11.2.2021		64	190	75	20	6,8	9,6	0,77	5 200 000	Metropolilab
SHIP3	passanger	18.1.2021		320	610	70	32	6,2	18	10	3 600 000	Metropolilab
SHIP3	passanger	20.1.2021		630	980	410	70	6,5	21	3,1	33 000 000	Metropolilab
SHIP3	passanger	25.1.2021		520	900	130	40	6,3	16	2,6	170 000 000	Metropolilab
SHIP4	cargo	6.11.2020		590	820	140	29	6,2	17	2,9	52 000 000	Metropolilab
SHIP4	cargo	13.11.2020		650	990	220	38	6,2	25	9,6	5 200 000	Metropolilab
SHIP4	cargo	20.11.2020		210	570	160	330	7,3	110	18	6 100 000	Metropolilab
SHIP4	cargo	22.10.2020		320	640	140	72	9,3	32	5	460 000	Metropolilab
SHIP4	cargo	30.10.2020		530	620	180	30	6,8	22	4,3	18 000 000	Metropolilab
SHIP5	cargo	1.3.2021	680		1300	340	120	7,1	160	17	>10 000 000	Kymlab
SHIP5	cargo	8.3.2021	560		990	310	110	7,2	150	20	3 200 000	Kymlab
SHIP5	cargo	18.1.2021	250		1000	170	110	7,0	140	17	3 000 000*	Kymlab
SHIP5	cargo	18.2.2021	800		1200	330	110	6,7	130	16	2 600 000	Kymlab
SHIP5	cargo	24.2.2021	820		1100	460	110	6,9	130	20	5 700 000	Kymlab
SHIP6	cargo	11.3.2021	380		660	120	58	6,5	17	6,5	3 900 000	Kymlab
SHIP6	cargo	15.2.2021	290		600	97	29	6,5	17	4,8	3 400 000	Kymlab
SHIP7	cargo	2.10.2020		203	470	200	160	7,4	10	1,9	190 000	Metropolilab
SHIP7	cargo	2.10.2020		14	47	9,5	6,4	7,6	1,7	0,15	22 000	Metropolilab
SHIP7	cargo	7.12.2020		430	870	310	850	7,5	25	6,6	330 000	Metropolilab
SHIP7	cargo	11.1.2021		100	490	420	680	7,3	15	3,9	8 000	Metropolilab
SHIP8	cargo	15.12.2020	240		440	62	430	7,0	67	48	>100 000	Kymlab
SHIP8	cargo	20.1.2021	240		470	99	160	7,1	52	22	4 000 000	Kymlab
SHIP8	cargo	23.2.2021	380		1300	640	160	7,1	110	24	140 000	Kymlab
SHIP9	cargo	10.2.2021	300		460	99	42	6,8	29	5,4	800 000*	Kymlab
SHIP9	cargo	20.4.2021	280		1200	580	140	7,8	140	20	600 000*	Kymlab
SHIP10	cargo	17.2.2021	53		170	3,9	450	6,8	110	74	<100	Kymlab
SHIP10	cargo	14.1.2021	5,1		270	4,9	430	6,7	140	85	<10	Kymlab
SHIP10	cargo	23.3.2021	< 3		350	1,9	380	6,3	100	88	0	Kymlab
SHIP11	cargo	2.3.2021	460		2300	76	21	10,6	36	6,9	4 100	Kymlab

*esimate

Average concentrations of different parameters in grey water.

All ships

	BOD mg/l	BOD ATU mg/l	COD mg/l	Suspended solids mg/l	Chloride mg/l	pH	Tot. N mg/l	Tot. P mg/l
min	< 3	14	47	1,9	6,4	5,8	1,7	0,15
max	820	1300	2400	640	850	11	160	88
mean	359	352	751	203	142	7,1	53	14

Cargo ships

	BOD mg/l	BOD ATU mg/l	COD mg/l	Suspended solids mg/l	Chloride mg/l	pH	Tot. N mg/l	Tot. P mg/l
min	< 3	14	47	1,9	6,4	5,8	1,7	0,15
max	820	1300	2400	640	850	10,6	160	88
mean	359	470	871	224	189	7,2	68	19

Passenger ships

	BOD ATU mg/l	COD mg/l	Suspended solids mg/l	Chloride mg/l	pH	Tot. N mg/l	Tot. P mg/l
min	58	140	23	12	6,2	6,1	0,2
max	630	980	410	70	7,3	27	10
mean	215	450	153	24	6,8	15	2,3

Passenger ships

		BOD5 ATU kg/d	COD kg/d	Suspended solids kg/d	Chloride kg/d	pH	Tot. N kg/d	Tot. P kg/d
SHIP2	7.1.2021	9,4	27,5	10,3	0,8	0,3	0,7	0,2
	11.1.2021	3,0	11,0	4,3	0,6	0,4	0,6	0,1
	13.1.2021	3,5	9,5	2,7	0,7	0,3	0,5	0,02
	18.1.2021	6,5	20,1	10,5	0,7	0,3	0,8	0,1
	20.1.2021	2,2	5,3	0,9	0,5	0,3	0,5	0,01
	25.1.2021	2,4	5,4	0,9	0,3	0,1	0,1	0,01
	11.2.2021	3,0	6,5	12,0	0,6	0,2	0,4	0,01
SHIP2	**Mean**	4,3	12,2	5,9	0,6	0,3	0,5	0,1
SHIP3	7.1.2021	11,5	23,9	3,8	0,9	0,3	1,2	0,1
	18.1.2021	31,0	59,1	6,8	3,1	0,6	1,7	1,0
	20.1.2021	29,5	45,9	19,2	3,3	0,3	1,0	0,1
	25.1.2021	8,8	15,2	2,2	0,7	0,1	0,3	0,04
	11.2.2021	2,0	6,1	2,4	0,6	0,2	0,3	0,02
SHIP3	**Mean**	16,6	30,0	6,9	1,7	0,3	0,9	0,3

Cargo ships

	BOD 5 kg/d	BOD5 ATU kg/d	COD kg/d	Suspended solids kg/d	Chloride kg/d	Tot. N kg/d	Tot. P kg/d
SHIP1		0,5	0,9	0,2	0,1	0,03	0,00
SHIP4		2,0	3,1	0,7	0,4	0,2	0,03
SHIP5	1,3		2,3	0,7	0,2	0,3	0,04
SHIP6	0,7		1,3	0,2	0,1	0,04	0,01
SHIP7		0,4	0,9	0,5	0,8	0,03	0,01
SHIP8	0,8		2,1	0,8	0,7	0,2	0,1
SHIP9	0,8		3,4	2,4	0,3	0,2	0,04
SHIP10	0,1		0,8	0,0	1,2	0,3	0,2
SHIP11	1,3		6,6	0,2	0,1	0,1	0,02

Map of the assumed discharge location.