OSPAR COMMISSION

Losses of contaminants from ships' coatings and anodes

A study relating to the Netherlands Continental Shelf and the North Sea

Monitoring and Assessment Series

2009

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998.
La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

Acknowledgement

This report has been prepared by C. van der Tak, Maritime Research Institute Netherlands (MARIN), for the Ministry of Transport, Public Works and Water Management of the Netherlands as OSPAR task manager for the assessment of losses of hazardous substances from ships’ coatings and anodes. MARIN report no. 22776.620/2. Final report. 4 November 2008.

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Contents

Executive Summary

This study undertakes to estimate the magnitude of losses of tributyltin and other biocides, copper, zinc and cadmium from ships' coatings and anodes for the Netherlands' Continental Shelf. Estimates are based on Automatic Identification System (AIS) data which is the best knowledge currently available on ship movements and characteristics. Uncertainties remain as estimates of losses depend on a variety of parameters and factors.

Estimates for the Netherlands' Continental Shelf suggest that in 2007 some 3.8 tonnes of tributyltin (TBT) have been lost by leaching from paints on ship hulls (at sea and in inland waters), with highest rate of losses in or close to harbours like Rotterdam. TBT has been used in the past in anti-fouling paints to protect ship hulls from the settlement of organisms. Over the past decade, TBT has been continuously phased out in Europe based on OSPAR, EU and national measures and its use is expected to cease in future with the global ban on the use of TBT in antifouling paints on ships which entered into force in 2008. Copper and Irgarol (cybutryne) are the main substitutes for TBT and have been used as anti-foulants for more than a decade. While less harmful than TBT, they still rely on their toxic effects on organisms to prevent settlement on the ship hull. Some 46 tonnes of copper and 852 kg of Irgarol are estimated to have leached from ship paints into the sea of the Netherlands' Continental Shelf in 2007. The highest rate of copper losses is found along the main shipping routes and the approach to, and in main harbours. A new generation of so-called non-sticky paints which do not use biocides is under development.

Zinc, aluminium and cadmium are the main metals used in ship anodes for protecting ship hulls from corrosion. Estimates for the Netherlands' Continental Shelf suggest that in 2007 some 145 tonnes zinc, 12 tonnes aluminium and 72 kg cadmium have leached from anodes to the sea.

Extrapolation of the results for the Netherlands' Continental Shelf to the entire Region of the Greater North Sea suggests that losses of contaminants from ships' coatings and anodes are 6 to 7 times those estimated for the Netherlands' Continental Shelf. The regional estimate is however associated with high uncertainties as the situation relating to ship traffic and shipping parameters such as leaching factors differs in the various areas of the North Sea.

Récapitulatif

La présente étude vise à évaluer l'importance des pertes de tributylétain et d'autres biocides, cuivre, zinc et cadmium provenant du revêtement et des anodes de navires pour le plateau continental néerlandais. Les estimations se fondent sur les données du Système d'identification automatique (SIA) qui constitue la meilleure source actuelle des connaissances sur les déplacements et les caractéristiques des navires. Des incertitudes subsistent car l'estimation des pertes dépend de divers paramètres et facteurs.

Les estimations relatives au plateau continental néerlandais suggèrent qu'en 2007 les pertes de tributylétain (TBT) par lixiviation provenant de la peinture utilisée sur les coques de navire (en mer et dans les eaux intérieures) s'élèvent à environ 3,8 tonnes, les pertes les plus importantes ayant lieu dans des ports tels que Rotterdam, ou à proximité de ceux-ci. Le TBT était utilisé dans les peintures antisalissures de protection des coques de navire contre la colonisation d'organismes. Au cours des dix dernières années, le TBT a été progressivement éliminé en Europe, grâce aux mesures d'OSPAR, de l'UE et nationales et on prévoit que son utilisation va cesser grâce à l'interdiction mondiale de son utilisation, dans les peintures antisalissures appliquées sur les navires, qui est entrée en vigueur en 2008. Le cuivre et l'irgarol (cybutryne) sont les principaux produits de remplacement du TBT et sont

utilisés comme antisalissure depuis plus de dix ans. Ils sont moins dangereux que le TBT mais ce sont leurs effets toxiques pour les organismes qui empêchent leur colonisation sur les coques de navire. On estime que les apports de la lixiviation dans la mer des peintures utilisées sur les navires correspondent à environ 46 tonnes de cuivre et 852 kg d'irganol dans le plateau continental néerlandais en 2007. Les pertes les plus élevées de cuivre se produisent le long des principaux couloirs de navigation et à l'entrée et à l'intérieur des ports principaux. Des peintures de nouvelle génération, dites non adhérentes, et n'utilisant pas de biocides sont en cours de développement.

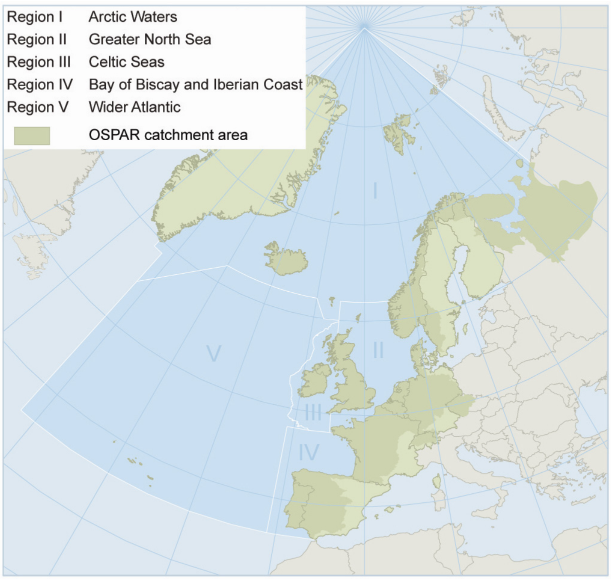
Le zinc, l'aluminium et le cadmium sont les principaux métaux utilisés dans les anodes des navires permettant de protéger les coques de navires contre la corrosion. Les estimations relatives au plateau continental néerlandais suggèrent qu'en 2007 les pertes par lixiviation dans la mer, provenant des anodes, s'élèvent à environ 145 tonnes de zinc, 12 tonnes d'aluminium et 72 kg de cadmium.

L'extrapolation des résultats, relatifs au plateau continental néerlandais, à l'ensemble de la région de la mer du Nord au sens large suggère que les pertes de contaminants provenant du revêtement et des anodes des navires sont de six à sept fois supérieures à celles estimées pour le plateau continental néerlandais. L'estimation régionale présente cependant d'importantes incertitudes car les caractéristiques et les divers paramètres de la navigation maritime, tels que les facteurs de lixiviation, varient d'une région à l'autre dans la mer du Nord.

1. Introduction

Ship hulls are exposed to corrosion and so-called fouling, the settlement of organisms on the hull's surface. While corrosion has direct impacts on the hull's integrity, fouling reduces the performance of the vessel and increases fuel consumption. Fouling on ship hulls is also one route for species from one part of the world to be introduced in other parts, giving rise to environmental concerns.

Metal-based anodes (especially zinc) are used to protect ship hulls against corrosion. In the past, anti-fouling paints for ship hulls have relied on biocides (e.g. TBT, copper) with toxic effects on organisms to prevent their settlement on the hull. Metals from anodes and active substances in ship hull coatings leach into the water. This report aims to estimate the magnitude of contaminants lost from ships' anodes and coatings to the sea.



The OSPAR Convention guides international cooperation on the protection of the marine environment of the North-East Atlantic. Work under the Convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Community.

OSPAR works under its Hazardous Substances Strategy to prevent pollution of the OSPAR maritime area and its Regions (see map) by continuously reducing discharges, emissions and losses of hazardous substances, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances.

Under OSPAR's Comprehensive Study on Riverine Inputs and Direct Discharges, OSPAR annually collects data from Contracting Parties on inputs of hazardous substances via rivers and through direct discharges from municipal and industrial effluents and mariculture in coastal waters. OSPAR also collects annual data from the offshore oil and gas industry on discharges of hazardous substances with produced water. To complement the picture of main land-based and sea-based inputs of hazardous substances, the Netherlands undertook a first estimate of the magnitude of losses of selected hazardous substances from sea ships in the Greater North Sea (OSPAR, 2006). This report updates the last assessment with estimates for the year 2007 and shows how previous estimates can be improved by using Automatic Identification System (AIS) data.

This report is a study on losses of tributyltin, biocides, copper, zinc and cadmium from ship antifouling coatings and anodes from ships on the Netherlands' Continental Shelf of the North Sea. It contributes to the OSPAR assessment of impacts of shipping on the marine environment (OSPAR 2009) and ultimately the Quality Status Report 2010.

The study also illustrates how average losses in Netherlands' waters can be used for extrapolation to give an estimate of inputs from sea ships in OSPAR Region II (Greater North Sea). However, losses in other areas of the Greater North Sea may differ for example due to difference in leaching factors. This causes uncertainties in the estimations for Region II and the results should be used with caution.

Chapter 2 describes the methodological approach followed. The estimates of losses of selected hazardous substances from sea ships for the Netherlands' Continental Shelf are presented in Chapter 3. An illustration of extrapolation to losses in the Greater North Sea is given in Chapter 4. The conclusions are summarized in Chapter 5.

2. Method for the assessment of contaminant losses

2.1 General

The amount of contaminants lost from ships' coatings and anodes is the product of the wet surface area (WSA) times the emission factors for the different substances. The different emission factors for the substances used in this report are described in Hulskotte and Oonk (2007).

A new element of this study is about determining shipping movements. Hulskotte and Oonk (2007) reconstructed voyages based on information on the port of departure, the port of destination and the types and sizes of the ships. In the present study Automatic Identification System (AIS) data of ships are used, which makes it possible to follow the ship during her sea voyage.

Section 2.2 describes AIS-data. Section 2.3 describes the approach to derived estimates of losses of contaminants using AIS-data. Section 2.4 explains the methodological problems that have been faced and how they were resolved.

2.2 Background and development of AIS

Automatic Identification System (AIS) is a system used by ships principally for identification of vessels at sea. AIS helps to resolve the difficulty of identifying ships when not in sight (e.g. at night, in fog, in radar blind arcs or shadows or at distance) by providing a means for ships to exchange ID, position, course, speed and other ship data with all other nearby ships and Vessel Traffic Service (VTS) stations. It works by integrating a standardized Very High Frequencies (VHF) transceiver system with a Global Positioning System (GPS) receiver and other navigational equipment on board ship (Gyro compass, Rate of turn indicator, etc.).

The IMO Convention on Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard all ships greater than/equal to 300 Gross Tonnes for international voyages.

The AIS-transceiver sends the following data every 2 to 10 seconds depending on the vessel's speed while underway, and every 3 minutes while a vessel is at anchor. This data includes:

- Maritime Mobile Service Identity (MMSI) number communication equipment - vessel's unique identification
- Navigational status - "at anchor", "under way using engine(s)", "not under command", etc
- Rate of turn - right or left
- Speed over ground
- Position accuracy
- Longitude and Latitude
- Course over ground
- True Heading
- Time stamp

In addition, the following data is broadcast every 6 minutes:

- MMSI-number - vessel's unique identification
- IMO-number - number remains unchanged upon transfer of the ship to other flag(s)
- Radio call sign - international radio call sign assigned to vessel
- Name
- Type of ship/cargo
- Dimensions of ship - to nearest metre
- Location and type of positioning system
- Draught of ship
- Destination - max 20 characters
- Estimated time of arrival (ETA) at destination

AIS was initially intended to increase safety at sea by early identification of other ships. However, soon after its introduction it became clear that AIS was also an excellent tool to get a picture of the ship traffic at sea, information which had previously only been obtainable through radar coverage.

One of the tasks of the Netherlands' Coastguards is to monitor the traffic and respond in case of emergencies. This task could be improved tremendously by using AIS. For this purpose a number of base stations (receivers) have been built along the Netherlands' coast. Depending on atmospheric disturbance, each base station can receive the messages in principle within a range of about 30 nautical miles. Additional base stations have been built since 2006 on offshore platforms. This growing network of base stations covers the whole southern part of the Netherlands' Continental Shelf. Only the northern point of the Netherlands' Continental Shelf is less well covered, but the density of shipping is relatively low in this area.

All AIS messages received by the base stations are sent to the Coordination Centre of the Netherlands' Coastguard in Den Helder where the ships' positions are projected on a large wall for operational (real time) purposes. Afterwards, the data is stored on tape and the tape is sent to the Maritime Research Institute Netherlands (MARIN). MARIN has permission to use the data for studies and to increase their knowledge of the actual pattern of ship movements on the North Sea. Use of the data is permitted on condition that the behaviour of individual ships is not recognizable in the results.

In Figure 2.1 the position of all AIS-targets (ships) were plotted for one week in June 2007 at 10-minute intervals. The black points represent ships with a course between 0° and 180° and the brown points refer to ships with a course between 180° and 360°. During this week the northern point of the Netherlands’ Continental Shelf was not covered. Only the data within the rectangle on the North Sea was delivered by the Netherlands’ Coastguard. The selected week of AIS data is not representative for the whole year 2007, because the area for which AIS data were delivered changed a number of times during the year. That makes it difficult to indicate the accuracy of the results. In Figure 2.2 the same plot is given for one week in July 2008.

It can be stated that the accuracy in the southern part of the Netherlands’ Continental Shelf and along the coast is very good. No firm statement can be made on the accuracy of data for the northern part of the Netherlands’ Continental Shelf, but with the installation of additional base stations on offshore platforms in 2007 and 2008 the accuracy of data is continuously improving.

In Chapter 3 the AIS results are compared with data from the database of SAMSON, which is used to estimate the losses of contaminants to the Greater North Sea outside the Netherlands’ Continental Shelf.

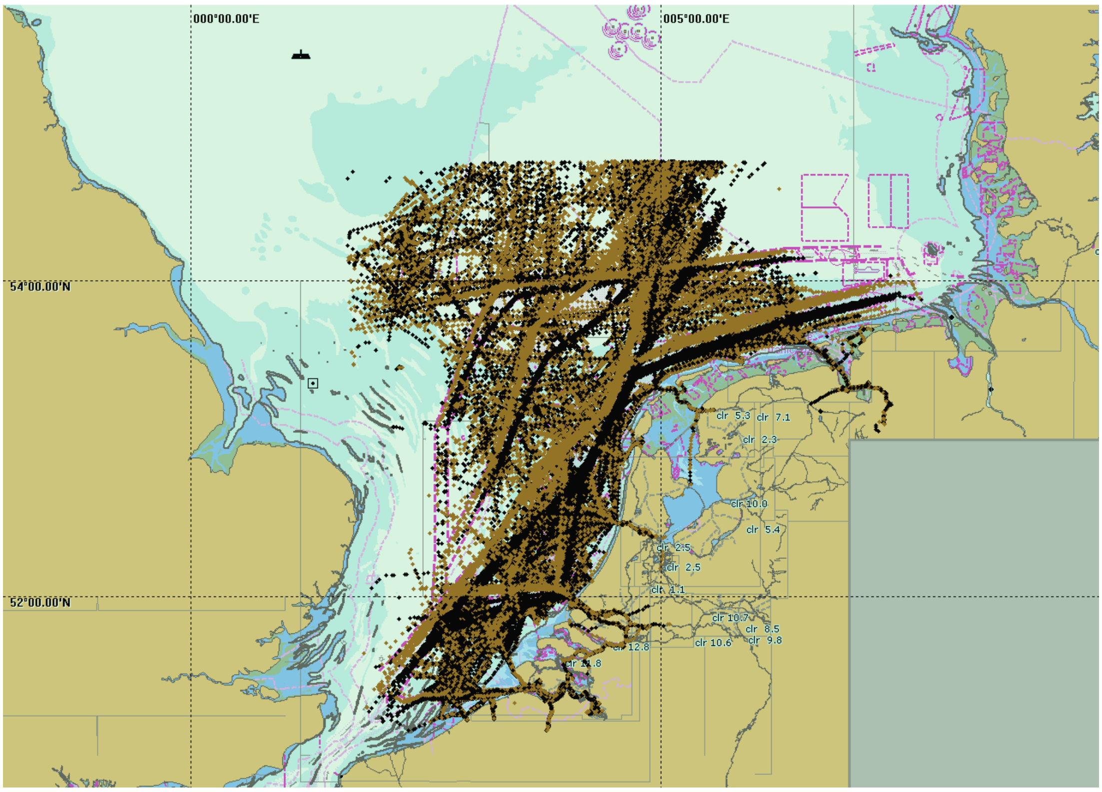


Figure 2.1 AIS-data, 1 week June 2007

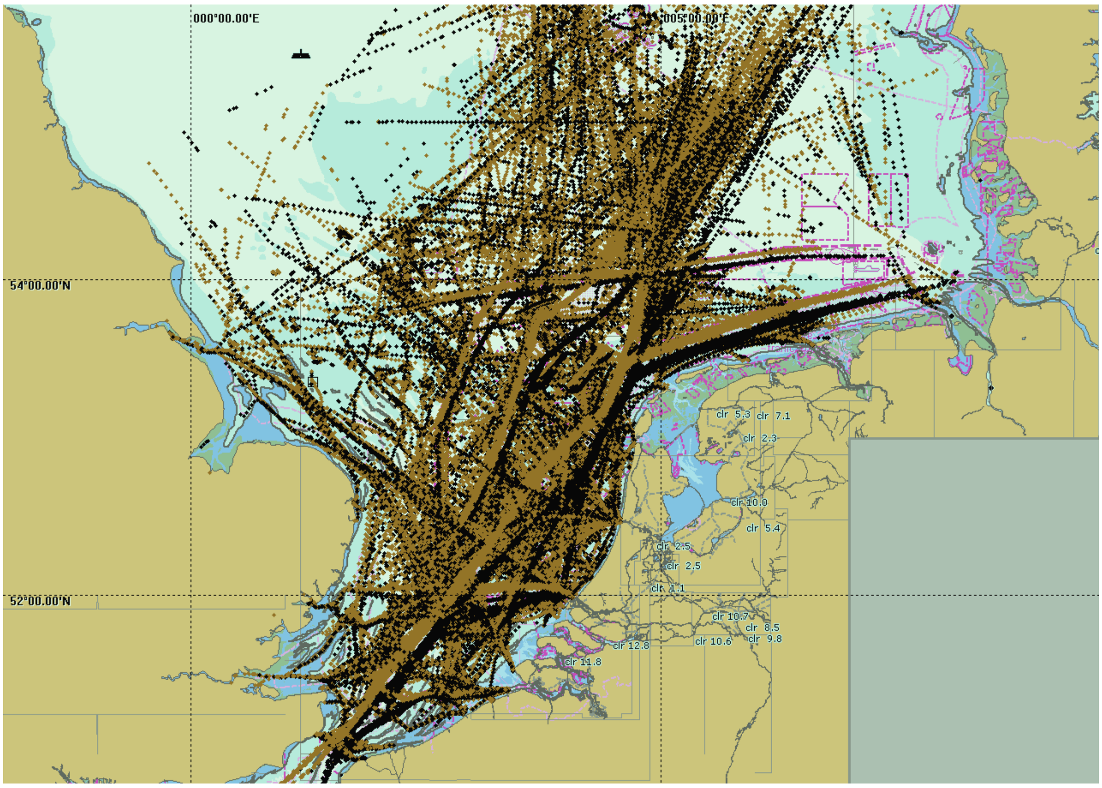


Figure 2.2 AIS-data, 1 week 2008

2.3 Approach to quantify the loss of contaminants on the Netherlands' Continental Shelf

To determine the spatial distribution of losses of contaminants from sea ships, the first requirement is to know the type, size and destination of ships. In the past this was done based on reconstructed voyages, but nowadays AIS-data is the most accurate source for this purpose. Since 2005 it has been mandatory for all ships above 300 GT, which means all merchant vessels and ferries, to have a transponder on board that sends messages continuously as described in Section 2.2. The databases and their components used in this study for the calculation of losses of contaminants are shown in Figure 2.3.

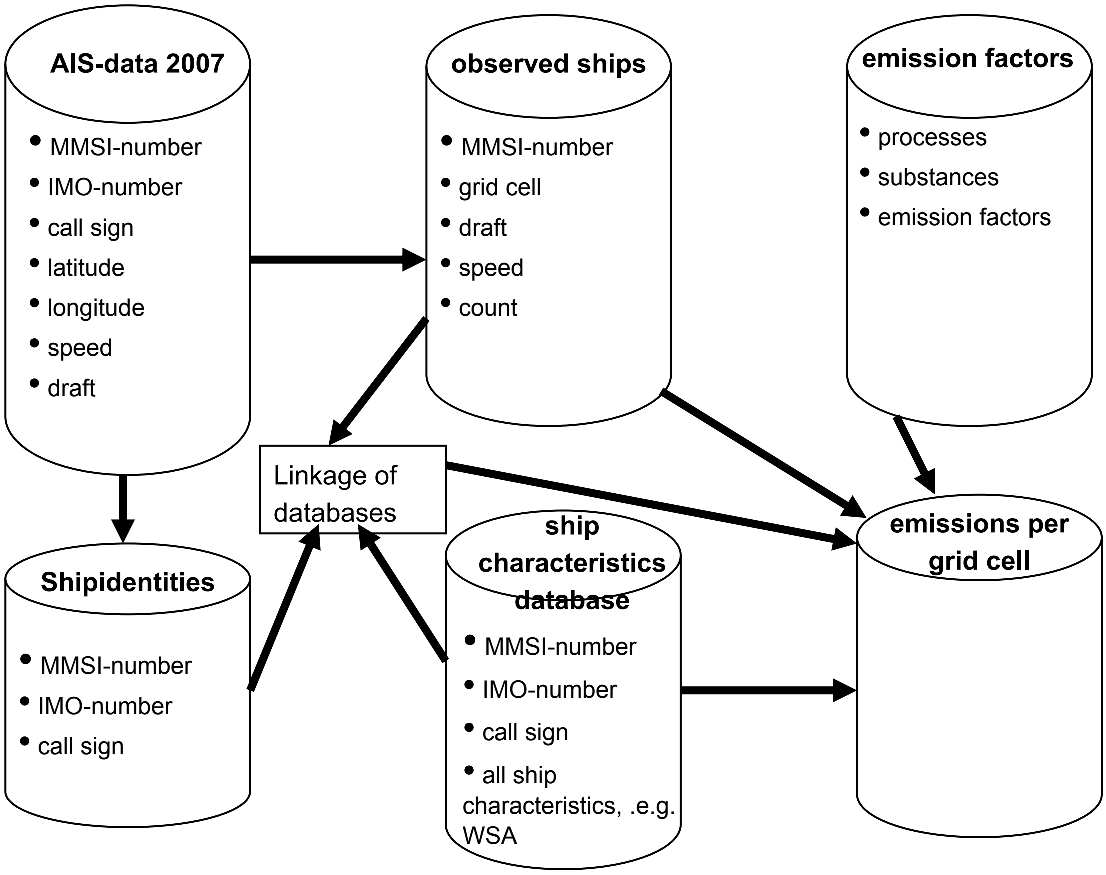


Figure 2.3 Databases which have been composed and used for the calculation of losses of contaminants

The AIS-data of 2007 is used to determine the spatial distribution of the ships' movements. In addition, the size of the wet area of a ship is essential for estimating contaminant loss, as this can vary from 200 m^2 for a small ship to more than 20 000 m^2 for a large ship. For this reason, the AIS-data is linked with the ship characteristics database which contains the dimensions of the observed ship and thus provides the data necessary for calculating the ship's wet area. Information on the type of the ship is the key for the application of the set of emission factors.

Furthermore, the position of the ship is necessary to determine the spatial distribution of contaminant loss. The whole area is divided into grid cells of 5 x 5 km in which the ship movement for each ship is counted.

The ship's speed is important for emissions to the air and the draft of the ship is relevant for the wet area. These operational values are taken into account by using speed classes of 1 knot and draft classes of 1 m.

The raw AIS data is processed as follows. The ship traffic of 2007 is replayed completely and every two minutes the following data from all AIS targets in the area are stored in a database with observed ships:

- MMSI number
- Grid cell, indicating an area of 5 x 5 km
- Speed class
- Draft class

- Navigational status
- Counts

The navigation status can help to confirm whether or not a ship is at anchor or moored. However, the analysis has shown that the navigational status is not very accurate, because the crew needs to fill in this information manually. Connectors to the navigation aids of the ship automatically fill in the position information. This means that the position information is very accurate.

The field count contains the number of observations of the same ship with the same operational parameters within the same grid cell.

The replay has resulted in a database of observed ships with about 10 million records. The losses of contaminants in each grid cell could be calculated with this database. The MMSI-number is the key for linking the ships with a database with ship characteristics for almost 100 000 ships. The operational parameters speed and draft are necessary to apply the correct emission factors and/or the emission explanation variables.

In reality, the MMSI-number is not enough to find the corresponding ship in the ship characteristics database. Some ships use the same (default MMSI number of 1193046), which is very confusing because when these ships are in the area at the same time, it is not clear which ship has sent the message. This also considerably hinders the operational tasks in the Coastguard Centre and therefore it is expected that ships will be warned, so that in future this phenomenon will reduce.

However there are more problems with linking the MMSI-number with the correct ship in the ship characteristics database. For this reason the set with MMSI-numbers is analysed separately. The result of this analysis is found in Section 2.4.

2.4 Linkage of MMSI-number and ship characteristics database

For the analysis of the linkage of MMSI-numbers with ships in the ship characteristics database, a table is composed with the MMSI-number and the number of counts. Furthermore a database ‘shipidentities’ (see Figure 2.3) is composed from the AIS-data with the main characteristics of each ship; MMSI number, IMO number and call sign.

An overview of the results from the analysis is presented in Table 2.1.

Table 2.1 Analysis of MMSI-numbers

match	Description	different MMSI-numbers					average ships in area				
		1	2	3	4	5	1	2	3	4	5
0	MMSI-numbers >999000000	9036					0.94				
	MMSI-numbers <999000000	12685					581.11				
	MMSI-number found in ship db, that contains IMO-number		10451					465.28			
1	ShipIdentities (0, blank)			201					19.29		
2	ShipIdentities (blank, blank)			125					12.32		
	Check possible			10125					433.67		
3	IMO_equal				9957					425.36	
	IMO_not equal				168					8.81	
4	IMO_AIS = 100 * IMO					50					2.94
5	call sign equal					46					2.75
6	probably wrong, of which 9 MMSI numbers are removed because they exist twice in ship db					72					2.61
	MMSI-number not in ship db		2234					115.83			
7	via ShipIdentities.IMO			1102					34.61		
8	via ShipIdentities. CallSign			22					0.88		
				1110					80.35		
9	ship found in ship characteristic db, but db contains no IMO-number; ShipIdentities (0, blank) or (blank,blank)				154					19.91	
10	ShipIdentities (0, blank) or (blank,blank)				795					52.92	
11	shipIdentities (non blank,*) but not in ship db				161					7.52	

First, the MMSI-numbers above 999000000 were removed because these MMSI numbers do not exist and are used by the system for storing "strange" AIS-messages. In Table 2.1 this applies to 9036 different MMSI numbers that account for 0.94 objects/ships in the study area.

Next the 12 685 different MMSI-numbers, which are good for an average of 581.11 ships in the area, are analysed. In 10 415 cases the MMSI-number could be found in the ship database. This set is good for 465.28 ships on average in the area.

Ships whose MMSI-number is found in the ship characteristics database

Because the ship characteristics database contains an IMO-number and a call sign, one could check whether these values match the values in the AIS-data collected in 'shipidenties'. In 201 cases it could not be checked because the values in 'shipidentities' were 0 for the IMO-number and blank for the call sign, which is further indicated with (0, blank). In 125 cases it could not be checked because the IMO and call sign were both blank in the AIS-data.

Thus, a check was possible for 10 125 MMSI-numbers. The result was:

- The IMO-number of the AIS matched that of the ship characteristics database in 9957 cases providing certainty that the correct ship was found.
- The IMO-number did not match in 168 cases, for the following reasons:
  - In 50 cases the IMO-number in the AIS-data was followed by "00". In this case, it could be concluded that the correct ship was found.
  - In 46 cases the call sign was equal, thus also a correct linkage.
  - In 72 cases the IMO-number and call sign were not equal. These linkages were not correct. In 9 of these 72 cases the reason was that one MMSI-number was mentioned in two records of the ship characteristics database. The records with the wrong MMSI-number were removed.

Thus in total 63 of the 10 125 records (0.6%) were probably linked to a wrong ship.

Ships whose MMSI-number is not found in the ship characteristics database

This group contains 2234 records.

- In 1102 cases the link could be established by the IMO-number found in the AIS-data thus in the 'shipidentities' database.
- In 22 cases the ship was found via the call sign in the AIS-data.
- In 1110 cases no link could be established because the AIS-messages did not contain an IMO-number or call sign, thus 0 or blank values in the 'shipidentities' database.
  - A limited number of 154 ships could be found in the ship characteristics database, but these ships belong to the group that has no IMO-number. The reason why they had no IMO-number was that they were very small ships mostly operating in the port areas.
  - It is expected that the remaining ships of match 10 and 11 with respectively 795 and 161 ships belong to the same group of fixed objects and small ships. The density and spatial distributions of the observations for match 10, thus ships which could not be linked in any way with a ship of the ship characteristics database, are presented in Figure 2.4. These ships are mainly observed in port areas and on platform positions, which means that they probably have an AIS-transponder on the platform.

Based on this analysis it can be concluded that the AIS-messages with a MMSI-number in match 9, 10 or 11 can be skipped. Even in the case that some may belong to real ships, these would be very small and thus have a negligible impact on the estimate of contaminant losses from coatings and anodes.

For an extra validation of the preceding conclusions, the traffic is replayed for only the MMSI-numbers belonging to a certain match. During the replay the extra AIS-data, such as length, destination etc., could be made visible. This manual control has confirmed the conclusions made.

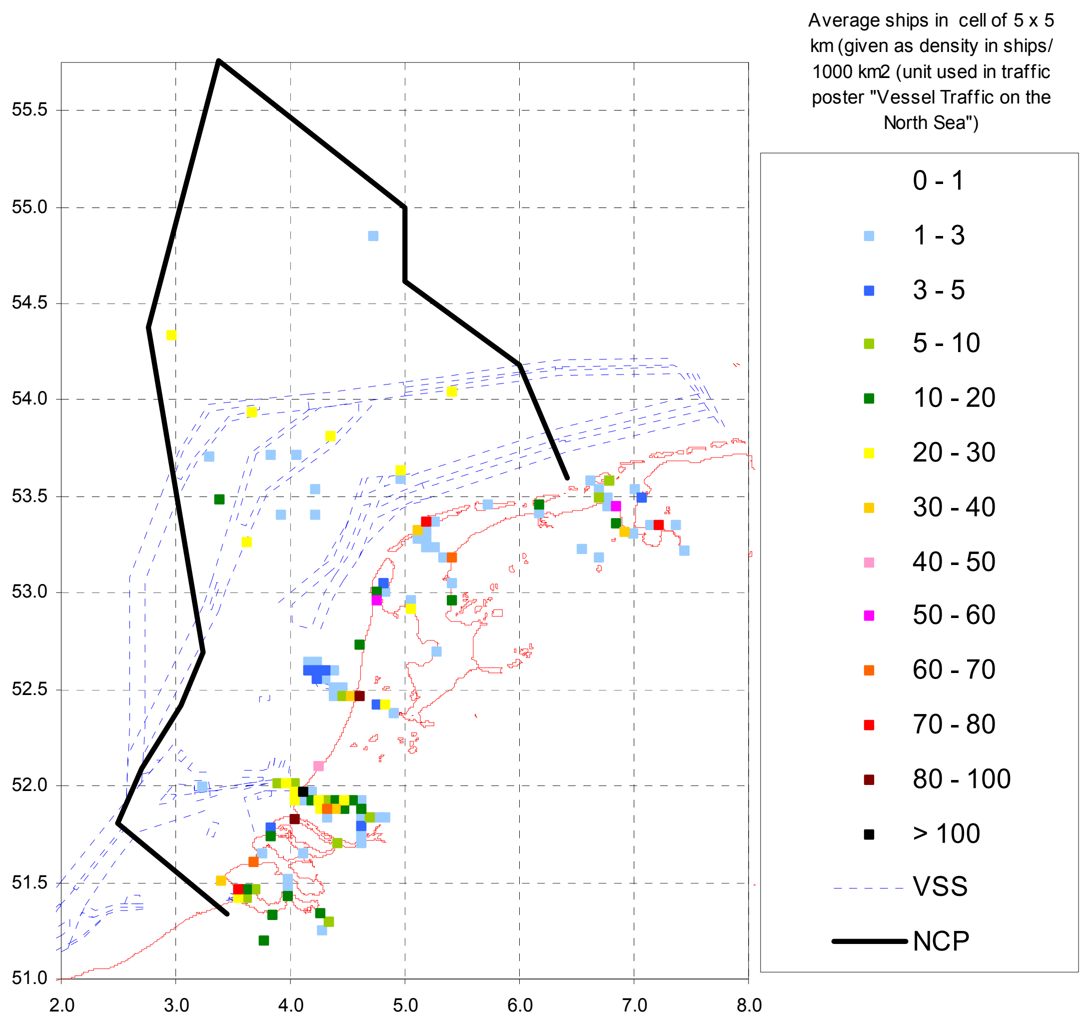


Figure 2.4 Density of ships belonging to match 10, impossible to link with a ship

2.5 Comparison AIS-data and SAMSON

While the AIS-data is the best source for determining the spatial distribution of ships on the Netherlands' Continental Shelf, it is useful to compare results where possible for validation. In this case, the numbers of observed ships on the Netherlands' Continental Shelf based on the AIS-data from 2007 are compared with the average number of ships calculated from the last traffic database of 2004 in the SAMSON-model. This traffic database of 2004 is also used to estimate the contaminant losses in OSPAR Region II.

Table 2.2 shows the average number of ships based on the AIS-data for 2007 and Table 2.3 gives the number of ships for 2004 from SAMSON. Three rows and one column are shaded grey in Table 2.2, because it is expected that most of these ships are not present in the SAMSON-traffic database. If the values in grey shaded cells are not counted, the average number of ships is 166.0 based on the AIS-data. This is 8.7% more than the 152.7 ships of SAMSON. The extra number of ships observed in 2007 is not equally distributed over the whole shipping matrix. Generally, it delivers the trend that was expected, as:

- A growth in the number of container ships from 14.5 in 2004 to 18.1 in 2007;
- Increase of the traffic in the higher size classes.

The differences are small, especially when it is taken into account that the calculated numbers in SAMSON are based on an assumed constant speed.

The main difference between the tables are found under the ship types miscellaneous and tug/supply of which 26.5 ships were observed in the AIS-data while the SAMSON-database contains only 5.1 ships, thus much lower. Many ships will presumably be classified as general dry cargo ships in SAMSON, which explains the 9.8 more ships in SAMSON than in AIS. But, even when this assumption is correct, there will still remain about 10 extra ships in the category miscellaneous and tug/supply. This number is also very plausible, because these types of ships do not sail from port A to port B (base of SAMSON) but mostly operate close to ports - assisting ships or performing other work.

It can be concluded that the observed number of ships very closely meets the calculated number of ships in SAMSON.

Table 2.2 Average number of ships sailing in Netherlands' Continental Shelf, composed from AIS-data of 2007

ship type	Size class in Gross Tonnage (GT)									Total
	<100	100-999	1000-1599	1600-49990	5000-9999	10000-29999	30000-59999	60000-99999	≥ 100000	
Unknown	0.001	0.230	0.021	0.019	0.005	0.001				0.276
OBO					0.036	0.005	0.107	0.070	0.036	0.254
Chemical	0.011	0.163	0.499	8.669	4.285	7.025	0.370			21.022
Oil tanker		0.093	0.084	1.297	0.751	2.093	2.305	2.218	0.202	9.042
LNG/LPG		0.001	0.119	3.212	0.533	0.524	0.081	0.009	0.003	4.482
Bulker		0.007	0.146	1.142	0.500	4.895	2.378	0.858	0.167	10.092
Container			0.114	2.377	4.866	3.594	3.409	3.357	0.417	18.135
RoRo		0.001	0.000	0.649	2.826	6.920	3.424	0.376		14.196
GDC	0.010	1.699	8.850	39.308	6.555	3.064	0.216			59.702
Pass/Ferry		0.185	0.010	0.040	0.042	1.190	1.079	0.124	0.021	2.691
Miscellaneous	0.020	4.610	2.071	3.714	1.665	0.894	0.046	0.044	0.005	13.071
Tug/supply	0.020	7.546	1.078	4.785	0.023	0.003				13.455
Fishing	0.102	1.776	0.233	0.347	0.110	0.018				2.585
(blank)	0.196									0.196
Total	0.361	16.312	13.225	65.559	22.197	30.225	13.416	7.056	0.851	169.201

Table 2.3 Average number of ships sailing in Netherlands' Continental Shelf, source traffic database of 2004 of SAMSON

ship type	Size class in Gross Tonnage (GT)								Total
	100-999	1000-1599	1600-49990	5000-9999	10000-29999	30000-59999	60000-99999	≥ 100000	
OBO			0.009	0.034	0.016	0.353	0.045	0.027	0.484
Chemical	0.434	0.493	8.683	3.803	5.651	0.118	0.005		19.186
Oil tanker	0.370	0.377	1.481	0.395	2.627	2.083	1.414	0.211	8.959
LNG/LPG		0.143	3.606	0.687	0.547	0.108			5.091
Bulker	0.187	0.121	1.466	0.845	5.789	2.045	0.859	0.149	11.461
Container		0.056	2.911	2.588	2.825	3.503	2.577		14.460
RoRo	0.003	0.042	0.730	3.170	8.410	3.144	0.100		15.599
GDC	3.870	11.907	44.497	6.109	2.846	0.252			69.480
Pass/Ferry	0.074	0.005	0.047	0.085	1.623	0.997	0.074	0.005	2.910
Miscellaneous	1.211	0.405	1.231	0.742	0.166	0.031	0.003	0.026	3.815
Tug/supply	1.262			0.018	0.002				1.282
Total	7.410	13.549	64.661	18.476	30.502	12.634	5.079	0.417	152.728

3. Contaminant losses on the Netherlands' Continental Shelf

For the calculation of the contaminant losses, all records with an MMSI-number belonging to match 1 through 8 of Table 2.1 were included. For each MMSI-number the wet area of the ship is calculated according the method described in Hulskotte and Oonk (2007). The wet surface area for each ship is calculated from the Gross Tonnage (GT) value with the formulae:

$$WSA_{max} = C\ GT^{2/3}$$

The value of the constant C is dependent on the ship type. The values of C are taken from Hulskotte and Oonk (2007) and presented in Table 3.1.

Table 3.1 Factor for calculation of wet surface area

Ship type nr	Ship type	C (factor for $GT^{2/3}$)
1	Oil tankers	9.62
2	Chemical tankers	9.35
2a	LNG tankers	7.47
3	Bulk carriers	9.70
4	Container	8.57
5	General dry cargo	8.76
6	Passengers and ferries	5.20
6a	Ro/Ro	6.60
7	Reefers	10.15
8,9,0	Miscellaneous	8.40

The table gives the factor for the calculation of the WSA for the maximal draft of the ship. However, most ships are not maximally loaded. The exposed WSA depends on the operational draft, which is sent out in the AIS-messages and stored in database of observed ships for the calculations of contaminant loss. The real WSA, thus for the operational draft is derived with the relation:

$$WSA = WSA_{max} (2 \%T + 2.6)/4.6$$

In which %T is the operational draft divided by the maximum draft.

Contaminant loss is calculated on a grid of 5x5 km. For each grid cell it is calculated which part of the grid cell area belongs to a certain geographical area. These geographical areas are defined in Hulskotte and Oonk (2007). By multiplying the losses in a grid cell with these factors, the losses in all defined geographical areas, thus also the main port areas of Rotterdam, Amsterdam and the Ems, could be determined.

The results of this study are implemented in the emission database EMS_COAT_ANS for coatings and anodes described in the factsheet Hulskotte and Oonk (2007). One has to keep in mind that this study does not include losses from fishing vessels. Table 3.2 contains the estimated loss of different substances by leaching from sea ship coatings and anodes. The losses on the Netherlands' Continental Shelf and port areas are spatially presented for TBT, Zinc, Copper and Cadmium in Figure 3.1 through Figure 3.4. When looking very critically at the figures a small change in colours can be found around the line where above the AIS-data is not always delivered (see Figure 2.1).

Table 3.2 Overview of losses of contaminants from coatings and anodes of sea ships on the Netherlands' Continental Shelf and in port areas in kg/year, fishing vessels excluded

Substance	Process	Inland waters			At sea			Grand Total
		berth	moving	total	At anchor	moving	total	
Aluminium	Corrosion anodes hull				2119	3519	5638	5638
	Corrosion anodes ballast tanks				2129	3141	5270	5270
	Corrosion anodes hull travellingtravelling on inland waters		622	622				622
	Corrosion anodes hull from at berth	902		902				902
Aluminium total		902	622	1524	4248	6660	10908	12432
Cadmium	Corrosion anodes hull				21	34	55	55
	Corrosion anodes ballast tanks				1	2	3	3
	Corrosion anodes hull travellingtravelling on inland waters		6	6				6
	Corrosion anodes hull from at berth	9		9				9
Cadium total		9	6	15	22	36	58	72
Dichlofluanide	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Dichlofluanide total		267	56	323	205	324	529	852
Irgarol	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Irgarol total		267	56	323	205	324	529	852
Copper	Leaching coatings at berth	14587		14587				14587
	Leaching coatings				11090	17539	28629	28629
	Leaching coatings travelling on inland waters		3039	3039				3039
Copper total		14587	3039	17626	11090	17539	28629	46255
Copperthiocyanaat	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Copperthiocyanaat		267	56	323	205	324	529	852
Seanine-211 (kathon)	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529

Substance	Process	Inland waters			At sea			Grand Total
		berth	moving	total	At anchor	moving	total	
	Leaching coatings travelling on inland waters		56	56				56
Seanine-211 (kathon) total		267	56	323	205	324	529	852
Tolylfluanide	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Tolylfluanide total		267	56	323	205	324	529	852
Tributyltin compounds	Leaching coatings at berth	1190		1190				1190
	Leaching coatings				891	1431	2322	2322
	Leaching coatings travelling on inland waters		249	249				249
Tributyltin compounds total		1190	249	1439	891	1431	2322	3761
Zineb	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Zineb total		267	56	323	205	324	529	852
Zinc	Corrosion anodes hull				41033	68146	109179	109179
	Corrosion anodes ballast tanks				2454	3621	6075	6075
	Corrosion anodes hull travelling on inland waters		12050	12050				12050
	Corrosion anodes hull from at berth	17676		17676				17676
Zinc total		17676	12050	29726	43487	71767	115254	144980
Zincpyri-thion	Leaching coatings at berth	267		267				267
	Leaching coatings				205	324	529	529
	Leaching coatings travelling on inland waters		56	56				56
Zincpyrithion total		267	56	323	205	324	529	852

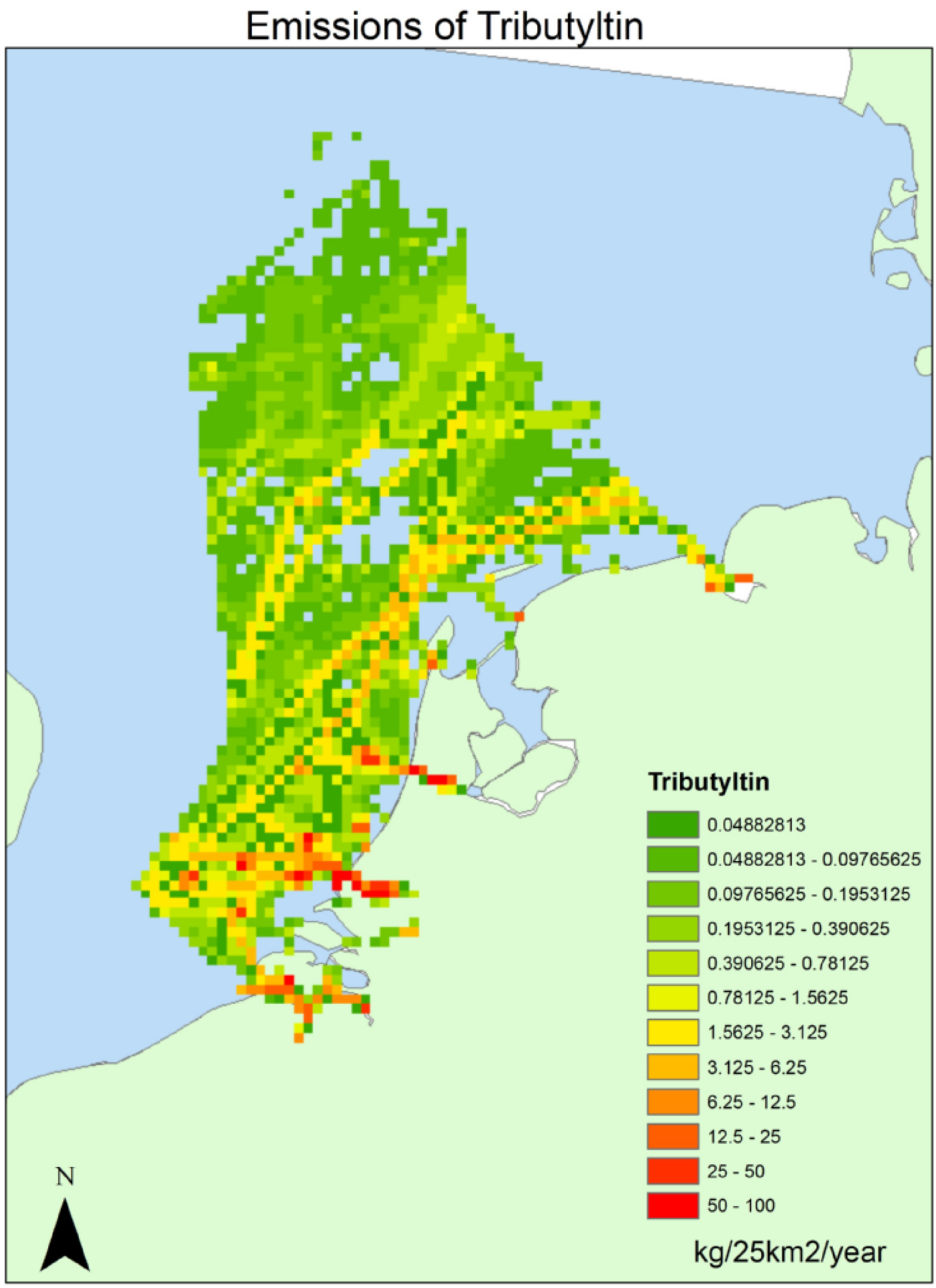


Figure 3.1 Emission of TBT by sea shipping

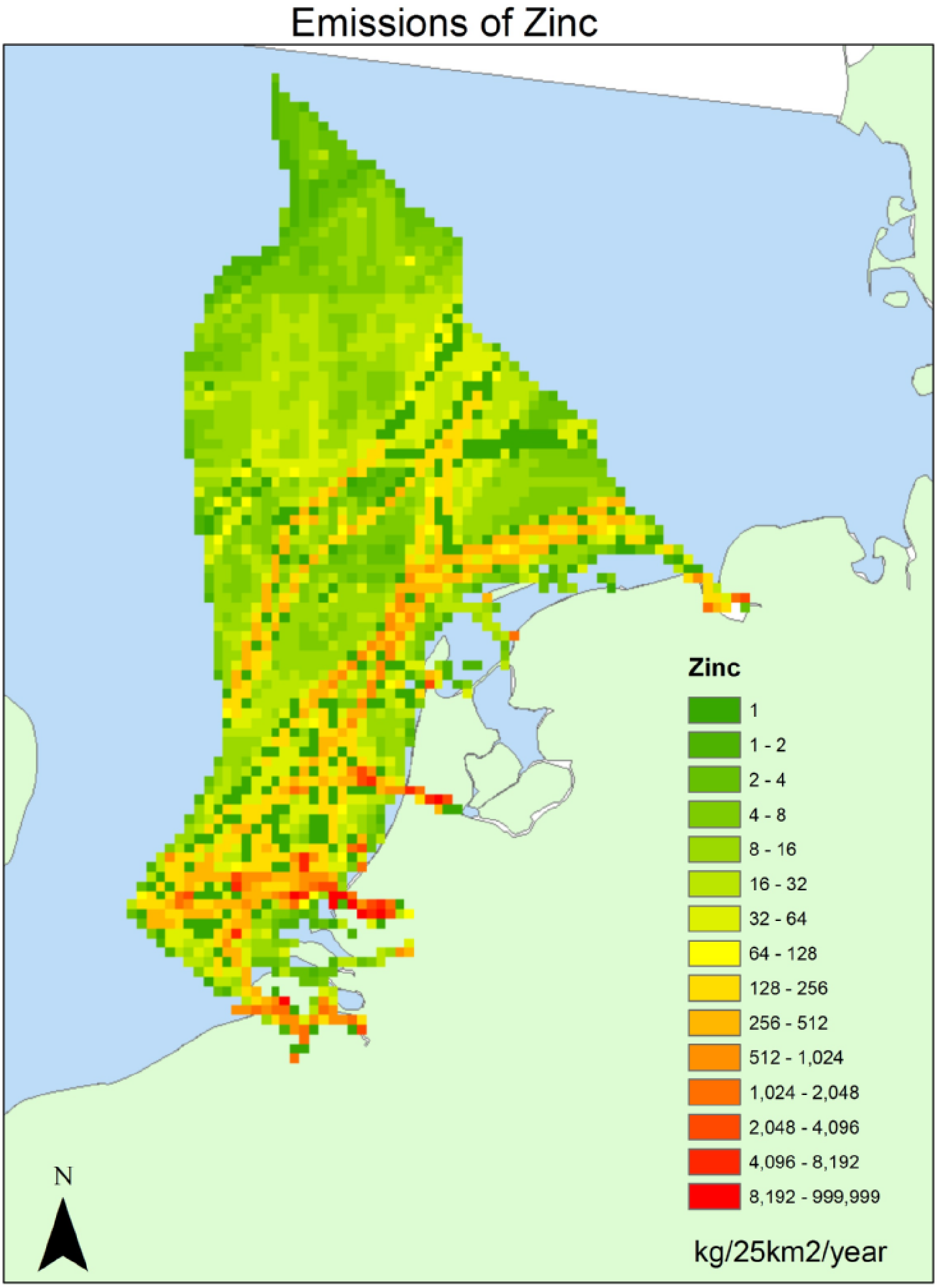


Figure 3.2 Emission of zinc by sea shipping

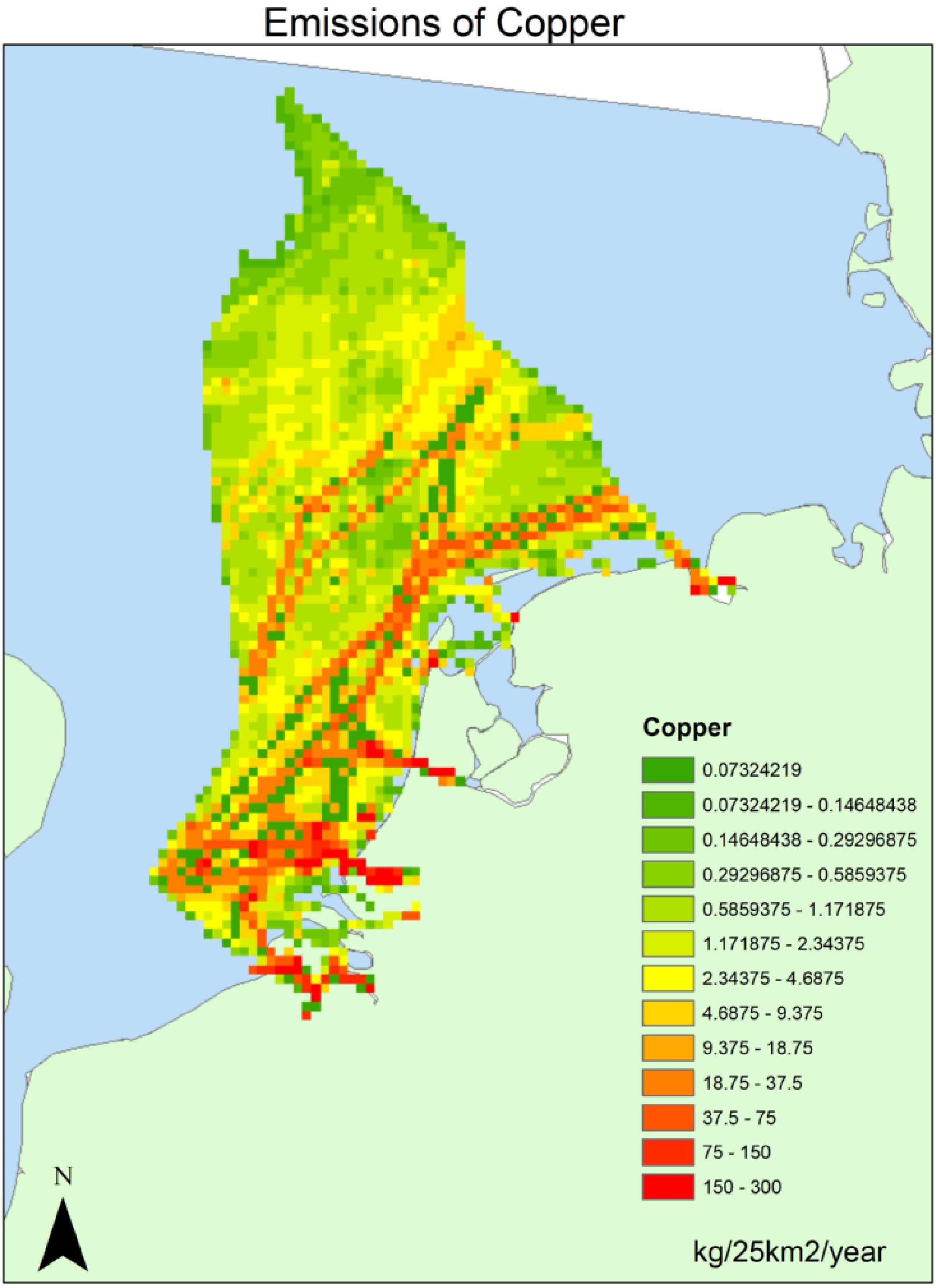


Figure 3.3 Emission of copper by sea shipping

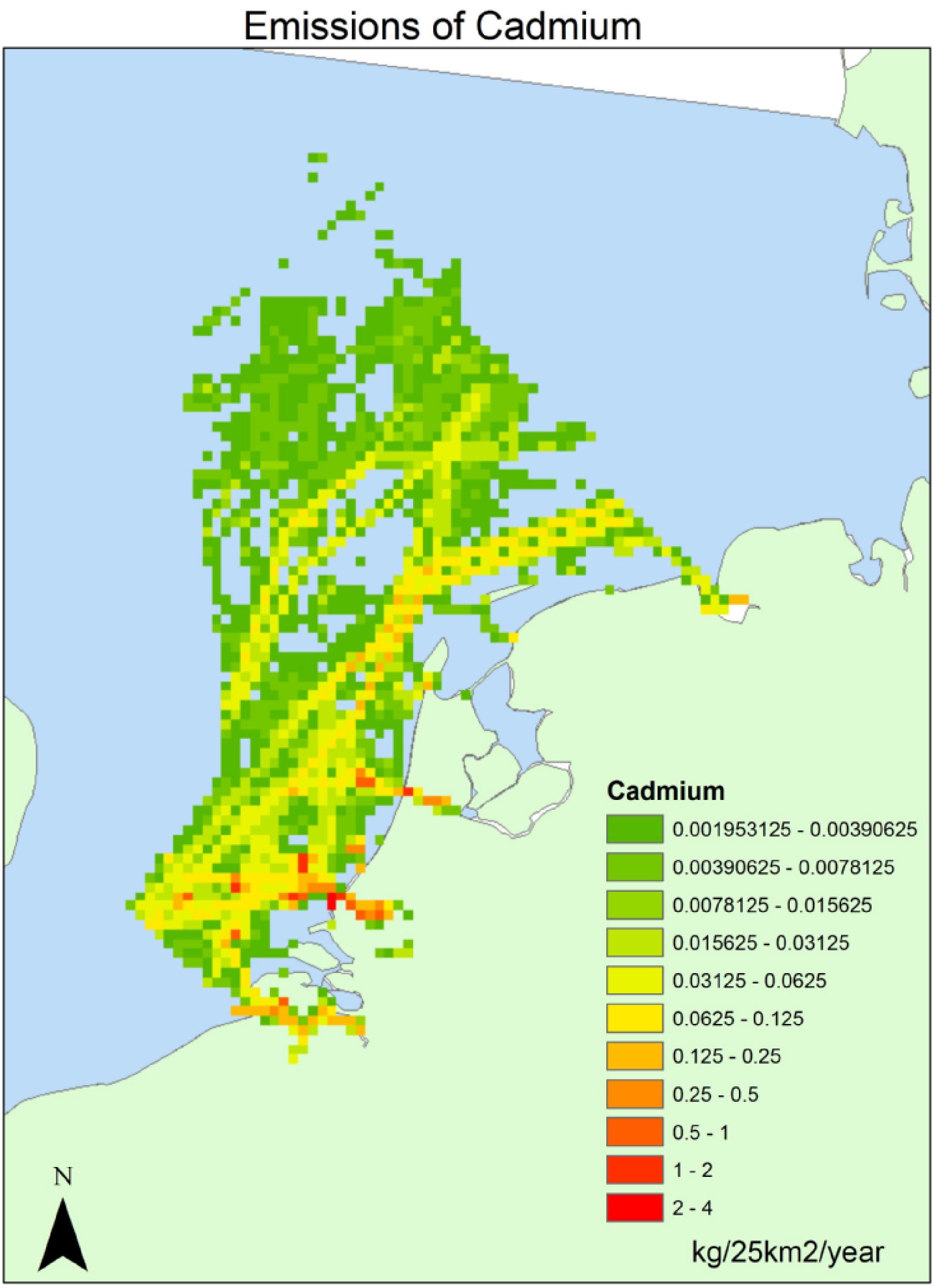


Figure 3.4 Emission of cadmium by sea shipping

4. Contaminant losses in OSPAR Region II, the Greater North Sea

OSPAR Region II (the Greater North Sea) is the area between 48° and 62° N and 5°W and 13°E. MARIN has no access to AIS-data for this whole area. For the estimation of contaminant losses in Region II an extrapolation has been performed based on the average contaminant loss on the Netherlands' Continental Shelf for each ship type and ship size and the number of ships in each type-size class in Region II. This is only done for the contaminant losses at sea and not for those in the port areas because the density of ships in ports is presumably high for the Netherlands due to the large port of Rotterdam.

The total contaminant losses for Region II are calculated with the formulae:

$$\text{Emission}_{\text{Greater North Sea}} = (\text{ships}_{\text{Greater North Sea}} / \text{ships}_{\text{NL Cont. Shelf}})\text{Emission}_{\text{Dutch NL. Shelf}}$$

In which the multiplication is performed on ship type and size level because the WSA is strongly dependent on the ship size. The number of ships in Region II and on the Netherlands' Continental Shelf is calculated from the 2004 SAMSON database with all routes based on the ship movements of one year, presented in Figure 4.1.

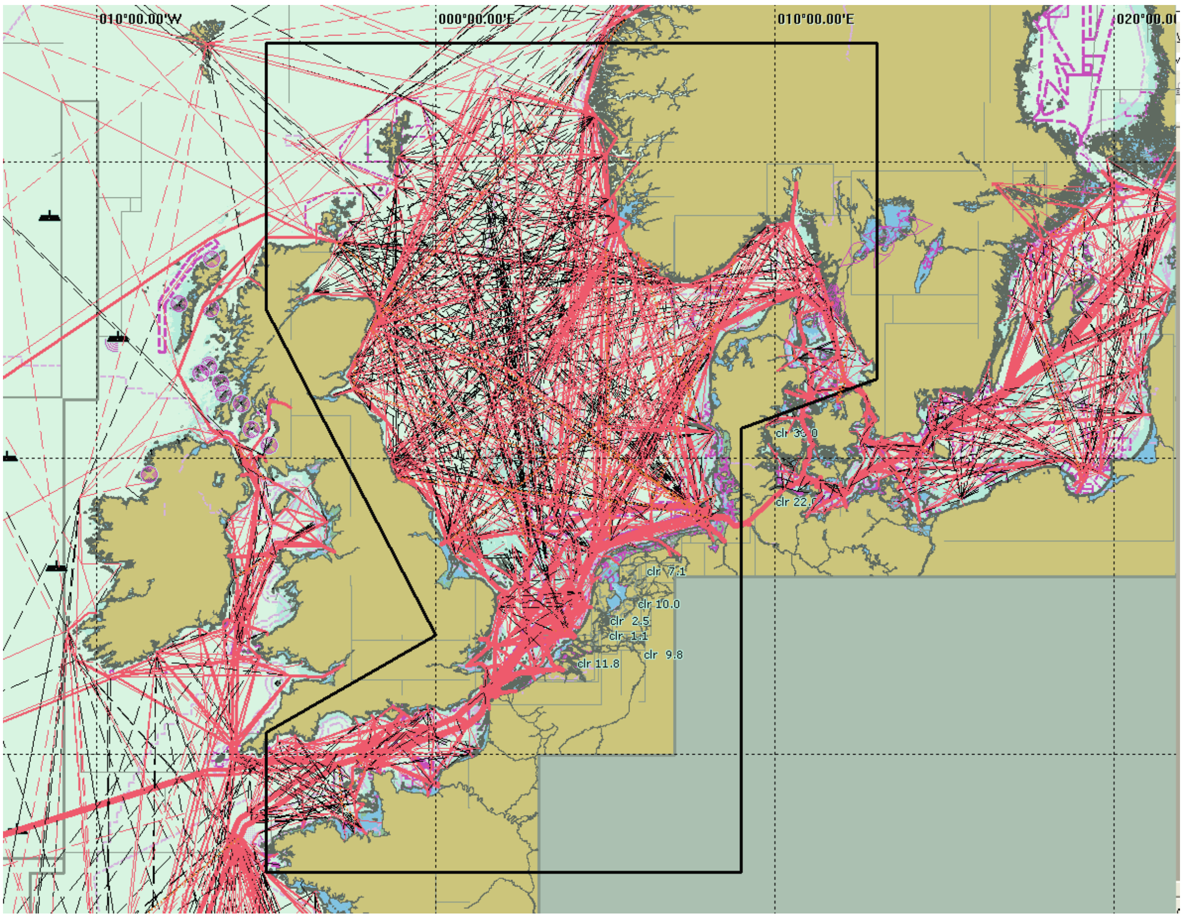


Figure 4.1 The OSPAR Region II with the traffic links

Table 4.1 Average number of ships sailing in OSPAR Region II, source traffic database of 2004 of SAMSON

ship type	Size class in Gross Tonnage (GT)								Total
	100-999	1000-1599	1600-49990	5000-9999	10000-29999	30000-59999	60000-99999	≥ 100000	
OBO	0.000	0.000	0.064	0.090	0.105	2.261	0.414	0.135	3.069
Chemical	2.627	2.689	43.802	18.390	29.804	1.059	0.076	0.000	98.447
Oil tanker	3.595	5.257	13.659	1.974	14.057	15.501	12.215	1.678	67.936
LNG/LPG	0.173	1.200	20.056	5.130	3.915	0.816	0.191	0.000	31.481
Bulker	1.099	0.833	10.920	5.127	33.860	12.580	6.262	0.792	71.473
Container	0.000	0.165	19.020	18.150	13.810	14.200	9.307	0.000	74.652
RoRo	0.049	0.158	6.043	21.043	36.475	14.235	0.419	0.000	78.422
GDC	28.785	65.496	237.140	33.880	17.396	0.961	0.000	0.000	383.658
Pass/Ferry	0.754	0.159	0.679	6.848	17.354	11.942	0.766	0.064	38.565
Miscellaneous	8.805	3.005	8.240	3.030	1.049	0.203	0.020	0.096	24.448
Tug/supply	6.619	0.000	0.000	0.540	0.029	0.000	0.000	0.000	7.188
Total	52.506	78.963	359.623	114.201	167.855	73.758	29.669	2.765	879.339

Table 4.1 compared with Table 2.3 shows that in Region II on average 5.8 (879.3/152.7) times more ships are sailing. A more detailed comparison of type size level shows that large container and RoRo ships are over-represented and that all sizes of passenger/ferries are under-represented for the Netherlands' Continental Shelf. Passenger/ferries have a share of 2% in the traffic on the Netherlands' Continental Shelf while their share is 4% in Region II due to the high ferry traffic in the Channel and between Denmark, Norway and Sweden.

Table 4.2 Losses of contaminants by leaching from coatings and anodes in kg/year in Region II; only moving ships at sea, fishing vessels excluded

Substance	Process	emissions in kg/year per year at sea, by moving ships
Aluminium	Corrosion anodes hull	19 745
	Corrosion anodes ballast tanks	17 684
	Aluminium Total	37 429
Cadmium	Corrosion anodes hull	191
	Corrosion anodes ballast tanks	10
	Cadmium Total	201
Dichlofluanide	Leaching coatings	1827
Irgarol	Leaching coatings	1827
Copper	Leaching coatings	98 986
Copperthiocyanaat	Leaching coatings	1827
Seanine-211 (kathon)	Leaching coatings	1827
Tolylfluanide	Leaching coatings	1827
Tributyltin compounds	Leaching coatings	8058
Zineb	Leaching coatings	1827
Zinc	Corrosion anodes hull	382 352
	Corrosion anodes ballast tanks	20 388
	Zinc Total	402 739
Zincpyrithion	Leaching coatings	1827

5. Conclusions

The quantification of losses of contaminants by leaching from ships' coatings and anodes on the Netherlands' Continental Shelf was successful, based on AIS-data for 2007. The conclusions and benefits are:

- More accurate spatial distribution of density of ship movement and contaminant losses by following the real routes of ships with AIS-data;
- Improvement of the estimate of density of ship movement, because ships are counted based on their real progress made and not on average speed;
- Improvement of the estimate of contaminant losses by using the real draft of ships from the AIS-data;
- Improvement of the estimate of contaminant losses for ships in anchorage areas, because from AIS-data the real type, size and time at anchor of the ship are known, while in the SAMSON database all ships at anchor are classified under ship type "ship at anchor";
- The number of observed ship movements from the AIS-data was in line with the number of ships calculated with SAMSON, with the exception of the ship types 'miscellaneous' and 'tug/supply', of which more ships were observed. This is plausible because most of these ships do not make voyages from port A to port B that are stored in the voyage database used by SAMSON, but carry out services at sea.
- The contaminant losses in ports, sailing to the berth and during the stay at the berth can be assessed with the same method.

Losses of contaminants from ships' coatings and anodes in OSPAR Region II, the Greater North Sea, can be estimated for moving ships by multiplying the losses for each ship type and size with the corresponding quotient of ships in OSPAR Region II and ships on the Netherlands' Continental Shelf. The ship traffic and associated losses of contaminants from ships' coatings and anodes is in OSPAR Region II about 6-7 times the losses on the Netherlands' Continental Shelf.

The extrapolation for contaminant losses from ships at anchor in OSPAR Region II is not performed because no data is available for ships in anchorage areas outside the Netherlands' Continental Shelf and it is expected that the number of anchorages as a fraction of the moving traffic on the Netherlands' Continental Shelf is not valid for the whole OSPAR Region II. The number of large ports and anchorage areas is high along the Netherlands' coast and not representative for the whole OSPAR Region II.

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