Assessment and Monitoring Series

Losses of Selected Hazardous Substances and Metals by Leaching from Sea Ships to the Greater North Sea

OSPAR Commission
2006

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.

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.

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Executive Summary/*Récapitulatif*

This document gives a first estimate of the magnitude of losses of TBT, biocides, copper, zinc and cadmium by leaching from antifouling coatings and anodes, used on sea ships, to the Greater North Sea. For the estimate, the Dutch estimation method (EMS Protocol) was applied to all Contracting Parties bordering the Greater North Sea. The estimates are based on a number of factors, such as:

- leaching rates for antifouling agents;
- application percentages of antifouling agents;
- total ‘wet surface’ of ships navigating the Greater North Sea each day;
- the number of ships navigating the Greater North Sea each day.

Le présent rapport donne une évaluation préliminaire de l’ampleur des pertes de TBT, de biocides, de cuivre, de zinc et de cadmium provenant de la lixiviation des revêtements antisalissure et d’anodes qui sont utilisés par les navires dans la mer du Nord au sens large. La méthode d’évaluation néerlandaise (protocole EMS) a été appliquée à toutes les Parties contractantes côtières de la mer du Nord au sens large. Les évaluations se basent sur un certain nombre de facteurs, tels que:

- *le taux de lixiviation en ce qui concerne les agents antisalissure;*
- *les pourcentages d’application des agents antisalissure;*
- *la “surface mouillée” totale des navires qui se déplacent chaque jour dans la mer du Nord au sens large;*
- *le nombre de navires navigant chaque jour dans la mer du Nord au sens large.*

Uncertainties in these factors cause uncertainties in the estimated losses of TBT, biocides, copper, zinc and cadmium from sea shipping.

Lorsque ces facteurs sont incertains, les évaluations des pertes de TBT, de biocides, de cuivre, de zinc et de cadmium provenant de la navigation sont également incertaines.

The leaching rate of copper for example can vary from 1 to 101 µg/cm^2/day according to van Hattum *et al.* (2002). In this document, an average leaching rate of copper of 50 µg/cm^2/day is taken based on expertise available within the CEPE Antifouling Working Group (CEPE, 1999). This simplification can result in an under- or overestimation of the calculated losses. The same accounts for the assumed application percentages of antifouling agents. Due to ‘new’ regulations with respect to allowed antifouling agents, application percentages of antifouling agents can change significantly over time (e.g. ban on TBT). The number of ships navigating the Greater North Sea each day is based on the data available in the databases of Statline and Eurostat. Inaccuracies and incompleteness of the data in these databases (for example, the number of fishing ships, offshore activity vessels, tugs and miscellaneous vessels in Eurostat have been provided by EC Member States on a voluntary basis and are therefore incomplete) result in errors in the estimated losses.

Le taux de lixiviation du cuivre, par exemple, peut varier de 1 à 101 µg/cm^2/jour, selon van Hattum et al. (2002). Dans le présent rapport on a utilisé un taux moyen de 50 µg/cm^2/jour en se basant sur l’expertise du groupe de travail antisalissure du CEPE (CEPE, 1999), ce qui peut entraîner une sous-estimation ou une surestimation dans le calcul des pertes. Il en est de même pour les pourcentages estimés d’application des agents antisalissure. Les pourcentages d’application des agents antisalissure peuvent varier considérablement dans le temps du fait de “nouvelles” réglementations sur les agents antisalissure autorisés (par exemple interdiction du TBT). Le nombre de navires navigant chaque jour dans la mer du Nord au sens large est calculé à partir de données provenant des bases de données Statline et d’Eurostat. Lorsque les données provenant de ces bases de données sont incorrectes ou incomplètes (par exemple, le nombre de navires de pêche, de navires ayant des activités offshore, de remorqueurs et de navires divers a été communiqué à la base de données d’Eurostat par des Etats membres de la CE, de manière facultative et il est donc incomplet) les pertes estimées présentent des erreurs.

With these uncertainties in mind, this document shows that losses of copper and zinc from sea ships to the Greater North Sea is quite substantial (14 – 19%) and is expected to increase with the substitution of TBT as antifouling agent by copper-based paints. In future work, the estimation of losses of substances from antifouling coatings and ship anodes can be improved by:

- determining the total 'wet surface' for ships navigating the waters of the continental shelves of all Contracting Parties bordering the Greater North Sea together, based on SAMSON and the Lloyd's database;
- collecting data on fishing ships, offshore activity vessels, tugs and miscellaneous vessels that visited the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004 (the data are provided by EC Member States to Eurostat on a voluntary basis and the data sets held by Eurostat are, therefore, not complete). These data are often available in national databases (e.g. Statline and Statbank Denmark);
- getting a better insight into the leaching rate of copper-containing antifouling coatings;
- getting a better understanding of the quantities of ballast water being released to the Greater North Sea.

Selon ce rapport, et en tenant compte des incertitudes ci-dessus, les pertes de cuivre et de zinc provenant de navires, dans la mer du Nord au sens large, sont assez importantes (15 à 20%). On s'attend de plus à une augmentation de ces pertes car des peintures à base de cuivre ont été substituées au TBT en tant qu'agents antisalissure. A l'avenir, on pourra améliorer l'estimation des pertes de substances provenant des revêtements antisalissure et des anodes des navires:

- *en déterminant la "surface mouillée" totale des navires navigant dans les eaux du plateau continental de toutes les Parties contractantes côtières de la mer du Nord au sens large. On se basera pour cela sur les bases de données SAMSON et de la Lloyd;*
- *en recueillant des données sur les navires de pêche, les navires desservant les activités offshore, les remorqueurs et les navires divers qui font escale dans les ports des Parties contractantes situées en bordure de la mer du Nord au sens large entre 1997 et 2004 (les données sont communiquées à la base de données d'Eurostat par des Etats membres de la CE, et les séries de données détenues par Eurostat sont donc incomplètes). Ces données sont souvent disponibles dans les bases de données nationales (par exemple: Statline et Statbank Denmark);*
- *en ayant un meilleur aperçu du taux de lixiviation des revêtements antisalissure à base de cuivre;*
- *en ayant une meilleure connaissance des quantités d'eau de ballastage rejetées dans la mer du Nord au sens large.*

1. Introduction[1]

1.1 General information

To prevent/diminish the colonisation of sea ships by barnacles, molluscs and algae, the exterior of ships is coated with antifouling agents. If ships were not treated with antifouling agents, fuel consumption would be 40% higher (CEPE fact sheet). The mechanism of action of antifouling coatings is related to the continuous slow release of toxic agents to water. The most widely applied antifouling coatings are:

- tin-containing antifouling coatings, like tributyltin methacrylate (TBTM), tributyltinoxide (TBTO) and trifenyltin (TFT);
- copper-containing antifouling coatings, like copperoxide and coppersulfide, and;
- biocides, like diuron, irgarol, chlorothalonil and dichlorofluanide.

Antifouling coatings on sea ships are not the only source of metal leaching to ocean water. In order to prevent corrosion, ships are equipped/treated with 'cathodic protection systems'. These systems use anodes that consist of relatively less inert metals. By application of anodes in an electrolyte environment (for example sea water), the relatively inert cathodic material of the ship is protected from corrosion by negative polarization of the cathode. The metals zinc (exterior and ballast tanks), copper (cooling installation) and aluminium (exterior, ballast tanks and cooling installations) are applied as anodes in sea shipping. Zinc is (still) the most widely applied material, while the use of aluminium is increasing. Aluminium has the advantage that it is more efficient (less material for the same effect), and that the alloy does not contain cadmium (in contrary to zinc alloys).

1.2 International policy

The application of tin-containing antifouling coatings on ships flying the flag of an EU Member State is forbidden since 1 July 2003 under European Community (EC) legislation (Regulation (EC) No 782/2003 on the prohibition of organotin compounds on ships). From 2008, tin-containing coatings are forbidden on all ships that visit EU harbours (application of a top-layer that prevents leaching is allowed). This regulation connects to the International Maritime Organisation (IMO) Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS-Convention). The Convention provides a worldwide ban of the application of antifouling paints from 2008. The AFS-Convention has not yet entered into force.

There are no regulations (planned) for the application of copper-containing antifouling coatings and biocides on ships. However, the biocide diuron has been designated as a priority substance (and is currently subject to a review for identification as priority hazardous substance) under the EC Water Framework Directive (WFD) (Directive 2000/60/EC).

There are no international arrangements on the use of anodes on ships. Cadmium (released by zinc-anodes), however, is a substance on the OSPAR List of Chemicals for Priority Action (OSPAR agreement 2004-12, as amended) and has been designated as a priority hazardous substance under the WFD.

1.3 OSPAR activities

The OSPAR objective with regard to hazardous substances is to prevent pollution of the maritime area 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. INPUT 2002 noted that there is a need to provide an overall picture of inputs of hazardous substances to the maritime area in order to be able to determine measures to prevent further pollution. The annual input of hazardous substances to the Greater North Sea via rivers (riverine inputs), from municipal and industrial outfalls in coastal waters and from offshore activities and dumping (direct discharges), and through atmospheric deposition (atmospheric inputs) is well studied. However, data on inputs from shipping activities, such

[1] Information is based on a report on quantitative information of losses of substances from shipping to waters of the Netherlands' Continental Shelf presented by the Netherlands to INPUT 2005 (INPUT 05/04/1).

as losses of hazardous substances by leaching from antifouling coatings and anodes, are hardly available.

At INPUT 2004, the Netherlands offered to provide an overview of activities and available data on losses of hazardous substances and certain metals by leaching from ships in the Greater North Sea. Contracting Parties were invited to provide the Netherlands with any national information on such losses, and on national policies and methodologies for estimating and recording losses by leaching from sea ships. In collecting this information from the various Contracting Parties, the Netherlands had received the following responses (status October 2005):

- Norway and Sweden submitted information on losses by leaching from ships in their waters, including TBT/TFT, copper and zinc (Appendix A);
- the UK has sought, but could not find, information regarding losses of hazardous substances by leaching from sea ships;
- Spain was still in the process of collecting the information;
- no response had been received from the other Contracting Parties.

Based on the information received it is not possible to quantify the amount of hazardous substances (TBT, biocides and cadmium) and certain metals (copper and zinc) lost by leaching from sea ships and to assess the importance of this source in relation to other sources (direct discharges and riverine and atmospheric inputs).

1.4 Aim of this study

To be able to present a first estimate of the amount of hazardous substances and certain metals entering the sea due to losses by leaching from sea ships, the Netherlands decided to calculate the input of TBT, biocides, copper, zinc and cadmium to the Greater North Sea by applying their national method for all Contracting Parties bordering the Greater North Sea. It was decided to do this only for the Greater North Sea – OSAPR Region II – since this is the best-studied area.

The main aims of this study are:

a. to estimate the quantities of TBT, biocides, copper, zinc and cadmium entering the Greater North Sea due to losses by leaching from antifouling coatings and anodes of sea ships;

b. to assess the importance of losses by leaching from sea ships in relation to other input sources (direct discharges and riverine and atmospheric inputs).

2. Methodology

2.1 Quantifying losses by leaching from ship coatings

2.1.1 Losses to waters of the Netherlands' Continental Shelf

Meijerink (2003) developed a method to calculate the quantities of TBT, biocides and copper entering the waters of the Netherlands' Continental Shelf (NCS) each year due to losses by leaching from antifouling coatings of sea and fishing ships. Losses from recreational shipping were not taken into account. The Dutch method estimates quantities of substances lost by leaching based on:

- leaching rates for antifouling agents (so called Leaching Factors);
- application percentages[2] for the different antifouling coatings, and;
- estimate of the total 'wet ship surface'[3] of the average number of ships navigating the waters of the NCS each day.

Since little is known about the relative application percentages for individual antifouling agents (e.g. TBTO), the quantities of lost substances are estimated for the group of tin-containing antifouling agents, copper-containing antifouling agents and biocides, respectively.

The Leaching Factors used for the calculations are obtained from the Mam-Pec study (van Hattum *et al.*, 2002). This study was part of the EC project 96/559/3040/DEB/E2, entitled 'Utilisation of more

[2] Application percentage: percentage of the ships that use a certain antifouling coating.
[3] Total wet ship surface: the surface of a ship that is situated underwater.

"environmentally friendly" antifouling products'. In the Mam-Pec study, average Leaching Factors were derived for the three main groups of antifouling agents, based on 1993 – 1998 literature data on leaching rates for individual antifouling agents.

The average Leaching Factors are:

- 50 µg/cm^2/day for copper-containing antifouling agents;
- 4 µg/cm^2/day for tin-containing antifouling agents, and;
- 2,5 µg/cm^2/day for biocide-containing antifouling agents.

Based on literature data, the following application percentages are used (Meijerink, 2003):

- 85% tin-containing antifouling coatings;
- 10% copper-containing antifouling coatings, and;
- 5% biocide-containing antifouling coatings.

Since the Leaching Factors and application rates are constants in the Dutch method calculating leaching values, year-by-year variations in leaching quantities are explained by differences in the total 'wet ship surface' of ships navigating the waters of the NCS each day.

The total 'wet ship surface' is calculated for different types and sizes of ships by application of the empirical formula of Mumford. The calculated average 'wet ship surface' is 3 533 m^2 for sea ships and 443 m^2 for fishing ships (Meijerink, 2003). These values are based on statistical data (for all ships navigating the waters of the NCS in 2000) from the Lloyd's database from 2000 and the risk model SAMSON[4]. To calculate quantities of losses by leaching from ship coatings for the years 1990, 1993-1999 and 2001-2002, the calculated 'wet ship surface' determined for the year 2000 is used and the ships that daily navigated the waters of the NCS in those years are based on figures on the number of ships that visited the Dutch harbours (Equation 1). These data are obtained from the Statline database of Statistics Netherlands (www.statline.nl).

Equation 1: $$X_{leach} = N_{ships} \times Surface_{wet} \times v_{leach-x} \times ap_x \times f \times rp_x \div 100{,}000{,}000$$

In which:

X_{leach}	=	the quantity of substance X leached from sea ships (tons/y)
N_{ships}	=	number of sea ships visiting the Dutch harbours each year
$Surface_{wet}$	=	average 'wet ship surface' (m^2)
$v_{leach-x}$	=	average Leaching Factor of substance X (µg/cm^2/day)
ap_x	=	application percentage of substance X
f	=	factor expressing the relation between the number of sea ships visiting the Dutch harbours each year and the number of sea ships navigating the waters of the NCS. In other words, this factor expresses the average number of days that a ship is navigating the waters of the NCS (day). This factor is 1,5388 for sea ships in the Netherlands in 2000.
rp_x	=	reduction percentage of substance X due to regulation on the use of antifouling coatings and anodes. In this study $rp_x = 1$

In the calculation it is assumed that:

- the number of ships visiting the Dutch harbours each year is related with the number of ships that navigate waters of the NCS each day (f = 1,5388 for sea ships), and;
- the type and size of ships navigating the waters of the NCS is constant over the years (1997 – 2002).

[4] SAMSON: Safety Assessment Model for Shipping and Offshore on the North Sea (model of RWS AVV Transport Research Centre).

2.1.2 Losses to the Greater North Sea (OSPAR Region II)

The method of Meijerink (2003) is used to calculate the losses of TBT, biocides and copper by leaching from antifouling coatings of sea and fishing ships to the Greater North Sea (Equation 1). For calculating the losses to the Greater North Sea, the same values were used for leaching rates, application percentages and 'wet ship surface' which have been used for calculating losses to waters of the NCS. Since the size, type and number of sea ships navigating the Greater North Sea each day in the period 1997 – 2002 was unknown (at the time of the preparation of this report), the number of ships visiting the harbours of the Greater North Sea was used as a measure to calculate the total 'wet ship surface' for the Greater North Sea. The number of ships visiting the harbours of the Greater North Sea each year can be retrieved from the Eurostat database (http://epp.eurostat.cec.eu.int). The data held by Eurostat on ships visiting harbours of EC Member States have been collected under Council Directive 95/64/EC on statistical returns in respect of carriage of goods and passengers by sea. Data collected on vessel movements in ports are limited to vessels loading and unloading goods and/or embarking and disembarking passengers. Directive 95/64 under which EC Member States report statistics to Eurostat does not cover fishing vessels, offshore activity vessels, tugs and miscellaneous vessels. Any such data held by Eurostat have been provided by EC Member States on a voluntary basis and are, therefore, not complete.

In the calculation it is assumed that:

- the relation between the number of ships visiting the Dutch harbours each year and the number of ships navigating the waters of the NCS each day (f = 1,5388 for sea ships) also holds for the number of sea ships visiting the harbours of the Contracting Parties bordering the Greater North Sea each year and the number of ships navigating the Greater North Sea each day;
- the type and size of ships navigating waters of the NCS is the same as the type and size of ships navigating the Greater North Sea (in other words, the average 'wet surface area' of ships is the same for the NSC and the Greater North Sea area), and;
- the type and size of ships navigating the Greater North Sea is constant over the years (1997 – 2002).

Before using the data from the Eurostat database, a check was made whether the Eurostat data agree with the data of Statline on the number of ships visiting the Dutch harbours each year.

An example how the losses of substances from ship coatings to the Greater North Sea are calculated is given in Appendix B using the example of losses of copper in 1997.

2.1.3 Uncertainties

Uncertainties in the estimate of quantities of substances lost by leaching from ship coatings to the Greater North Sea are, amongst others, caused by uncertainties in determining the:

- Leaching Factors;
- the application factor;
- the total 'wet surface' of ships navigating the Greater North Sea each day;
- the number of ships navigating the Greater North Sea each day.

2.2 Quantifying losses by leaching from ship anodes

2.2.1 Losses to waters of the Netherlands' Continental Shelf

Kuiper (2003) developed a method to calculate the quantities of copper, zinc, cadmium and aluminium entering the waters of the NCS each year due to leaching from anodes used on sea and fishing ships. Losses from recreational shipping were not taken into account. The Dutch method estimates the quantities of substances lost by leaching from anodes applied to ship hulls and ballast tanks based on:

- leaching rates of anodic materials (so called Leaching Factors);
- the total 'wet surface' of the average number of ships daily navigating waters of the NCS, and;
- the assumption that 50% of the total number of ships carrying ballast water release their water to waters of the NCS.

Leaching Factors take into account the corrosion rate of the anodic material, the exposure time (to water) and the application percentage of the specific anode. Corrosion rates were derived from data obtained from cathodic protection plans (CP-plans) for ships. For more details see Kuiper (2003) and Willems *et al.* (2003). Application percentages for zinc and aluminium anodes used on ship hulls, ballast tanks and electric anti-fouling systems for cooling installations were estimated based on information from anode suppliers, experts and ship-yards (Willems *et al.*, 2003).

The above-mentioned Leaching Factors are constants. Lost quantities of substances from anodes depend therefore on the total 'wet surface' (both wet exterior surface and inner surface of ballast tanks) of all ships navigating the waters of the NCS each day.

The total 'wet ship surface' is calculated for different types and sizes of ships by application of the empirical formula of Mumford. The calculated average 'exterior wet ship surface' for anodes is 4416 m^2 for sea ships and 553 m^2 for fishing ships (Kuiper, 2003). The calculated average 'interior wet surface of ballast tanks' for anodes is 1569 m^2 for sea ships and 202 m^2 for fishing ships (Kuiper, 2003). These values are based on statistical data from the Lloyd's database from 2000 and the risk model SAMSON. For the calculation of the quantities of hazardous substances and certain metals lost by leaching from sea ship anodes, similar assumptions apply as described in section 2.1.1.

2.2.2 Losses to the Greater North Sea (OSPAR Region II)

The method of Kuiper (2003) is used to calculate the quantities of zinc, cadmium and copper lost from anodes of sea and fishing ships to the Greater North Sea. For calculating these losses, the same values were used for the leaching rates, application percentages and 'wet ship surface' which have been used for calculating losses by leaching from coatings to waters of the NCS. Since the size, type and number of ships navigating the Greater North Sea each day in the period 1997 – 2002 was unknown (at the time of the preparation of this report), the number of ships visiting the harbours of the Greater North Sea each year were used as a measure to calculate the total 'wet ship surface' for the Greater North Sea. The number of ships visiting the harbours of the Greater North Sea each year can be retrieved from the Eurostat database (http://epp.eurostat.cec.eu.int). The data held by Eurostat on ships visiting EC Member States have been collected under Council Directive 95/64/EC on statistical returns in respect of carriage of goods and passengers by sea. Data collected on vessel movements in ports are limited to vessels loading and unloading goods and/or embarking and disembarking passengers. Directive 95/64 under which EC Member States report statistics to Eurostat does not cover fishing vessels, offshore activity vessels, tugs and miscellaneous vessels. Any such data held by Eurostat have been provided by EC Member States on a voluntary basis and are, therefore, not complete.

In the calculation it is assumed that:

- the relation between the number of ships visiting the Dutch harbours each year and the number of ships navigate the waters of the NCS each day (f =1,5388 for sea ships) also holds for the number of sea ships visiting the harbours of the Contracting Parties bordering the Greater North Sea each year and the number of ships navigating the Greater North Sea each day;
- the type and size of ships navigating the waters of the NCS is the same as the type and size of ships navigating the Greater North Sea (in other words, the average 'wet surface area' is the same for the NCS and the Greater North Sea area), and;
- the type and size of ships navigating the Greater North Sea is constant over the years (1997 – 2002).

Before using the data from the Eurostat database, a check was made whether the Eurostat data agree with the data of Statline on the number of ships visiting the Dutch harbours each year (section 3.1).

2.2.3 Uncertainties

Uncertainties in the estimate of quantities of substances lost by leaching from anodes of ships to the Greater North Sea are, amongst others, caused by uncertainties in determining the:

- Corrosion Factors;
- the application factor;
- the total 'wet surface' of ships navigating the Greater North Sea each day;
- the number of ships navigating the Greater North Sea each day.

2.3 Other input sources (direct discharges and riverine and atmospheric inputs)

The OSPAR website (http://www.ospar.org) has been examined for information on the input of TBT, biocides, copper, zinc and cadmium from various sources (direct discharges and riverine and atmospheric[5] inputs) to the Greater North Sea. Where more than one reference was found to inputs of TBT, biocides, copper, zinc and cadmium to the Greater North Sea, data from the most recent publication was used.

3. Results

Statistical information extracted from the Eurostat database is based on statistical data reported by EC Member States under Council Directive 95/64/EC of 8 December 1995 on statistical returns in respect of carriage of goods and passengers by sea.

3.1 Comparison of Statline and Eurostat data

The numbers of ships visiting the Dutch harbours between 1997 and 2004 listed in the Statline and Eurostat databases have been compared (Table 1) to determine if the data of the Eurostat database was suitable to estimate the losses of substances from antifouling coatings and anodes to the Greater North Sea using the Dutch model (based on Statline data).

Table 1. Numbers of sea ships and fishing ships visiting the Dutch harbours taken from the Eurostat and Statline databases. Differences in figures between the two databases are presented as percentage (%) in the column (Eurostat-Statline)/Statline*100.

Year	Statline[#1]		Eurostat[#1]		(Eurostat-Statline)/ Statline*100 (%)	
	Sea ships	Fishing ships	Sea ships	Fishing ships	Sea ships	Fishing ships
1997	42 830	543	45 449	62	6	-89
1998	42 681	546	45 188	42	6	-92
1999	42 401	540	46 041	30	9	-94
2000	43 142	528	45 994	54	7	-90
2001	43 406	524	45 883	37	6	-93
2002	42 858	511	45 792	47	7	-91
2003	42 562	-	46 136	79	8	-
2004	43 604	-	47 738	17	9	-

#1 The same harbours were selected from both databases (Amsterdam, Delfzijl, Eemshaven, Dordrecht, Harlingen, IJmuiden, Klundert, Moerdijk, Rotterdam, Scheveningen, Terneuzen, Vlaardingen, Vlissingen, Zevenbergen, Zaanstad and 'overige havens' (other ports)).

Table 1 shows that both databases agree well when it comes to the number of sea ships visiting the Dutch harbours. The Eurostat data on sea ships visiting the Dutch harbours are 6 – 9% higher than those of the Statline database. These differences are acceptable with regard to the intended calculations. The data of the two databases on fishing ships visiting Dutch harbours differ, however, significantly. The reason for this is that the statistics collected by Eurostat under Council Directive 95/64/EC does not cover movements of fishing vessels; any such information held by Eurostat has been provided by EC Member States on a voluntary basis and is, therefore, not complete. The number of fishing ships visiting the harbours of the other European countries bordering the Greater North Sea is either low (United Kingdom) or missing all together (all other countries) in the Eurostat database. It was, therefore, not possible to calculate the losses of TBT, biocides, copper, zinc and cadmium from antifouling coatings and anodes of fishing ships to the Greater North Sea.

5 Atmospheric input: calculations are based on "Method 3a".

3.2 Number of ships visiting the harbours of the Greater North Sea (1997 – 2002)

The following countries/harbours were selected from the Eurostat database as basis for calculating the number of ships visiting the harbours of the Greater North Sea between 1997 and 2002. It should be noted that for some countries derogations from reporting under Directive 95/64/EC applied in the period 1997 – 2000 causing discontinuities in the time series:

- Netherlands (all harbours);
- Belgium (all harbours);
- Germany North Sea (all harbours);
- Sweden North Sea (all harbours);
- Norway (all harbours);
- Denmark (all harbours, except Kobenhavn, Arhus, Odense, Kalundborg and Svendborg);
- France Atlantic and North Sea (all harbours except Brest, La Rochelle, Nantes Saint-Nazaire, Bordeaux and Bayonne);
- UK (all harbours except Bristol, Cardiff, Port Talbot, Swansea, Milford Haven, Newport, Holyhead, Liverpool, Manchester, Fleetwood, Heysham and Stranrear).

This selection results in a slight overestimation of the number of sea ships visiting the harbours of the Greater North Sea because some harbours of other maritime areas were also included (for example some harbours in OSPAR Region I (Arctic Waters) since all harbours of Norway were included).

The data sets held by Eurostat were not complete for all Contracting Parties bordering the Greater North Sea. There were, for example, no data on the number of ships visiting the harbours of Norway in the period 1997 – 2001. Such data gaps were filled with the average number of ships visiting the harbours of the Contracting Party concerned each year based on all data available (for example, the average number of ships visiting the harbours of Norway between 2002 and 2004 was used as a measure for the period 1997 – 2001).

All registered ships of the above mentioned Contracting Parties were selected from the Eurostat database. These Eurostat data and complementary OSPAR estimates show that the number of ships visiting the harbours of the Greater North Sea between 1997 and 2004 varies from about 660 000 to 750 000 (Table 2).

Table 2. Number of (registered) ships visiting the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004. Source: Eurostat database and OSPAR estimates.

Year	1997	1998	1999	2000	2001	2002	2003	2004
Netherlands	45 511	45 230	46 071	46 048	45 920	45 839	46 215	47 755
Belgium	31 929	32 031	30 484	32 760	32 252	31 661	30 326	30 264
Germany	28 701	29 350	29 616	65 426	67 837	68 405	68 205	85 993
Sweden	16 233	16 702	15 900	12 697	11 756	11 368	11 114	11 213
Norway	33 637	33 637	33 637	33 637	33 637	32 358	30 887	37 666
Denmark	399 141	375 766	345 642	330 283	323 501	345 314	344 308	349 412
France	13 579	12 448	14 710	46 030	48 076	50 275	51 932	50 114
UK	141 702	141 702	141 702	139 769	147 115	144 557	141 055	136 015
Total sea ships	**710 433**	**686 866**	**657 762**	**706 650**	**710 094**	**729 777**	**724 042**	**748 432**

Explanatory notes to the statistics from European Commission/Eurostat:
The data on ships visiting Member States' harbours were collected according to Council Directive 95/64. During the period 1997 – 1999 data collection from Member States was subject to various legal derogations. This may explain the break in series. Data collected on vessel movements in ports are limited to vessels loading/unloading goods and/or embarking/disembarking passengers. Fishing ship movements are not collected. "Ro-ro passenger" vessels are included under "general cargo non-specialised vessels" (and not under passenger vessels).

An overview of the type and number of ships (cargo, passenger, fishing, offshore, miscellaneous or unknown) that visited the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004, and the number of harbours included from each Contracting Parties bordering the Greater North Sea (source: Eurostat database) is listed in Appendix C. Appendix C shows that most countries do not report the number of fishing ships visiting their harbours. For Germany and France, a remarkable increase in the number of ships visiting their harbours is observed in the period 1999 – 2000 and 1998 – 1999, respectively. This is the result of legal derogations from the reporting of the numbers of ships calling their ports which have been granted to these Member States for a transitional period following entry into force of Directive 95/64/EC in 1997. The number of cargo ships visiting those harbours of Denmark bordering the Greater North Sea each year (over 300 000) is very high compared with the number of cargo ships visiting the harbours of other Contracting Parties bordering the Greater North Sea. The number and type of ships visiting the Danish harbours between 1997 and 2004, as listed in the Eurostat database, were therefore compared with the information held by the database Statbank Denmark (www.statbank.dk). After consultation of Statbank Denmark, it appears that Eurostat and Statbank Denmark list passenger ships/ferries under different categories, with Eurostat regarding ferries as general cargo ships. Thus, the number of passenger ships/ferries that visited the Danish harbours each year is over 300 000 and the number of cargo ships is several tens of thousand. For the calculations of the losses of copper, zinc, cadmium, TBT and biocides by leaching from antifouling coatings and anodes of sea ships to the Greater North Sea, these differences are not very important, since the calculations are based on the total number of ships visiting the harbours of the Contracting Parties bordering the Greater North Sea. However, deficiencies in shipping statistics can result in under- or overestimation of the estimated losses from sea ships to the Greater North Sea calculated in this study.

3.3 Estimated total losses of substances from antifouling coatings and anodes to the Greater North Sea

The results of the calculation of quantities of copper, zinc, cadmium, TBT and biocides lost by leaching from antifouling coatings and anodes from sea ships between 1997 and 2002 are listed in Tables 3 – 7. No calculations were performed for the years 2003 and 2004, since the Dutch method is only ‘valid’ until the year 2002. The results for each substance are briefly described below.

3.3.1 Copper

The estimated total quantities of copper lost per year by leaching from antifouling coatings and anodes from sea ships to the Greater North Sea between 1997 and 2002 ranges from 287 tons per year (1999) to 315 tons per year (2002) (Table 3).

Table 3. Estimated total quantities of copper (tons) lost by leaching from antifouling coatings and anodes from sea ships to the Greater North Sea between 1997 and 2002.

Copper (tons)	1997	1998	1999	2000	2001	2002
Ship antifouling coatings	193	187	179	192	193	198
Ship anodes (electric antifouling)	118	114	108	116	115	117
Total	311	301	287	308	308	315

3.3.2 Zinc

The estimated total quantities of zinc lost per year by leaching from antifouling coatings and anodes from sea ships to the Greater North Sea between 1997 and 2002 ranges from 1 664 tons per year (1999) to 1 820 tons per year (2002) (Table 4).

Table 4. Estimated total quantities of zinc (tons) lost by leaching from anodes from sea ships to the Greater North Sea between 1997 and 2002.

Zinc (tons)	1997	1998	1999	2000	2001	2002
Ship anodes (exterior)	1 522	1 471	1 406	1 519	1 511	1 538
Ship anodes (ballast tanks)	280	271	258	278	277	282
Total	1 802	1 742	1 664	1 797	1 788	1 820

3.3.3 Cadmium

The estimated total quantities of cadmium lost per year by leaching from anodes of sea ships to the Greater North Sea between 1997 and 2002 ranges from 0,8 to 0,9 tons per year (Table 5).

Table 5. Estimated total quantities of cadmium (tons) lost by leaching from anodes of sea ships to the Greater North Sea between 1997 and 2002.

Cadmium (tons)	1997	1998	1999	2000	2001	2002
Ship anodes (exterior)	0,8	0,7	0,7	0,8	0,8	0,8
Ship anodes (ballast tanks)	0,1	0,1	0,1	0,1	0,1	0,1
Total	0,9	0,8	0,8	0,9	0,9	0,9

3.3.4 TBT

The estimated total quantities of TBT lost per year by leaching from antifouling coatings of sea ships to the Greater North Sea between 1997 and 2002 ranges from 122 tons per year (1999) to 135 tons per year (2002) (Table 6).

Table 6. Estimated total quantities of TBT (tons) lost by leaching from antifouling coatings of sea ships to the Greater North Sea between 1997 and 2002.

TBT (tons)	1997	1998	1999	2000	2001	2002
Ship antifouling coatings	131	127	122	131	131	135
Total	131	127	122	131	131	135

3.3.5 Biocides

The estimated total quantities of biocides lost by leaching from antifouling coatings of sea ships to the Greater North Sea between 1997 and 2002 ranges from 4 to 5 tons per year (Table 7).

Table 7. Estimated total quantities of biocides (tons) lost by leaching from antifouling coatings of sea ships to the Greater North Sea between 1997 and 2002.

Biocides (tons)	1997	1998	1999	2000	2001	2002
Ship antifouling coatings	5	5	4	5	5	5
Total	5	5	4	5	5	5

3.4 Relative importance of losses from ships in relation to other sources

The measured inputs of copper, zinc, cadmium, TBT and biocides to the Greater North Sea through riverine inputs, direct discharges, atmospheric inputs and estimated losses from sea ships between 1990 and 2002 are listed in Appendix D.

The data used for direct discharges and riverine inputs are those collected and assessed by OSPAR under the Comprehensive Study of Riverine Inputs and Direct Discharges (RID) (OSPAR agreement 1998-5, as amended). The data used for atmospheric inputs are those collected and assessed by OSPAR under the Comprehensive Atmospheric Monitoring Programme (CAMP) (OSPAR agreement 2001-7, as amended). References to the data sources are given in Appendix D.

No data could be found concerning inputs of TBT and biocides to the Greater North Sea from other sources (direct discharges and riverine and atmospheric inputs). Therefore no comparison could be undertaken of the estimated quantities of losses of TBT and biocides from ships with their inputs from other sources.

The results for copper, zinc and cadmium are visualised in Figures 1 – 3 and briefly described below, separately for each metal.

3.4.1 Copper

The inputs of copper to the Greater North Sea increase in the following order of sources (Figure 1):

Direct discharges < sea ship inputs (losses by leaching) < atmospheric inputs < riverine inputs

Approximately 14 to 19 % of all copper entering the Greater North Sea is due to losses of copper by leaching from antifouling coatings and ship anodes. This percentage equals the percentage of atmospheric inputs of copper in the year 2002. Figure 1 also shows that the riverine inputs of copper are increasing and that the direct discharges and atmospheric inputs of copper are decreasing. The quantities of copper lost by leaching from sea ships were relatively constant between 1997 and 2002.

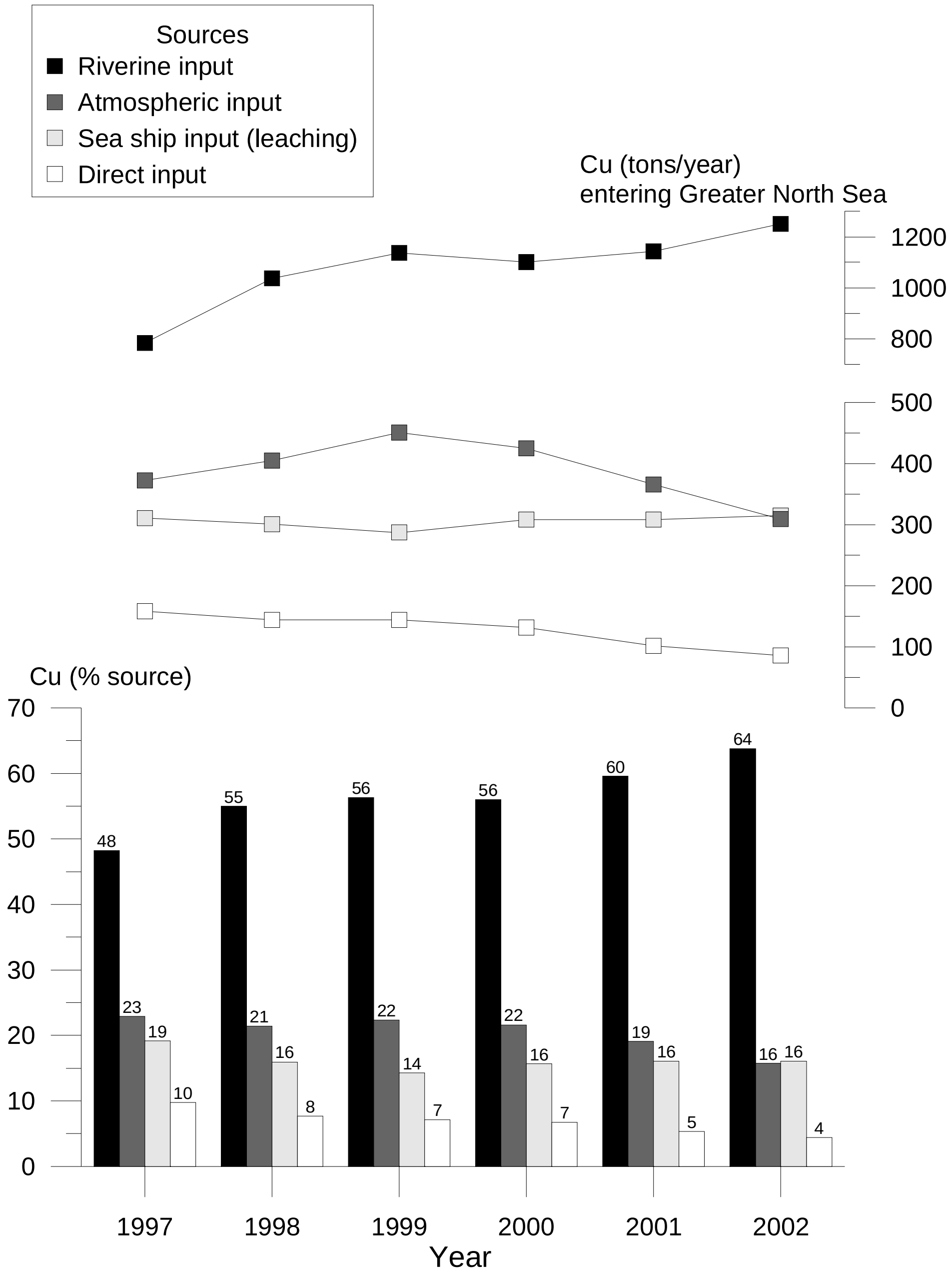

Figure 1. The input (both absolute and relative) of copper from various sources to the Greater North Sea.

3.4.2 Zinc

The inputs of zinc to the Greater North Sea increase in the following order of sources (Figure 2):

Direct discharges < sea ship inputs (losses by leaching) < atmospheric inputs < riverine inputs

Approximately 14 to 19 % of all zinc entering the Greater North Sea is due to losses of zinc by leaching from ship anodes. This percentage was quite stable between 1997 and 2002. The riverine inputs of zinc on the other hand increased between 1997 and 2002 whereas the direct discharges of zinc decreased. The quantities of zinc entering the Greater North Sea via atmospheric deposition are relatively constant.

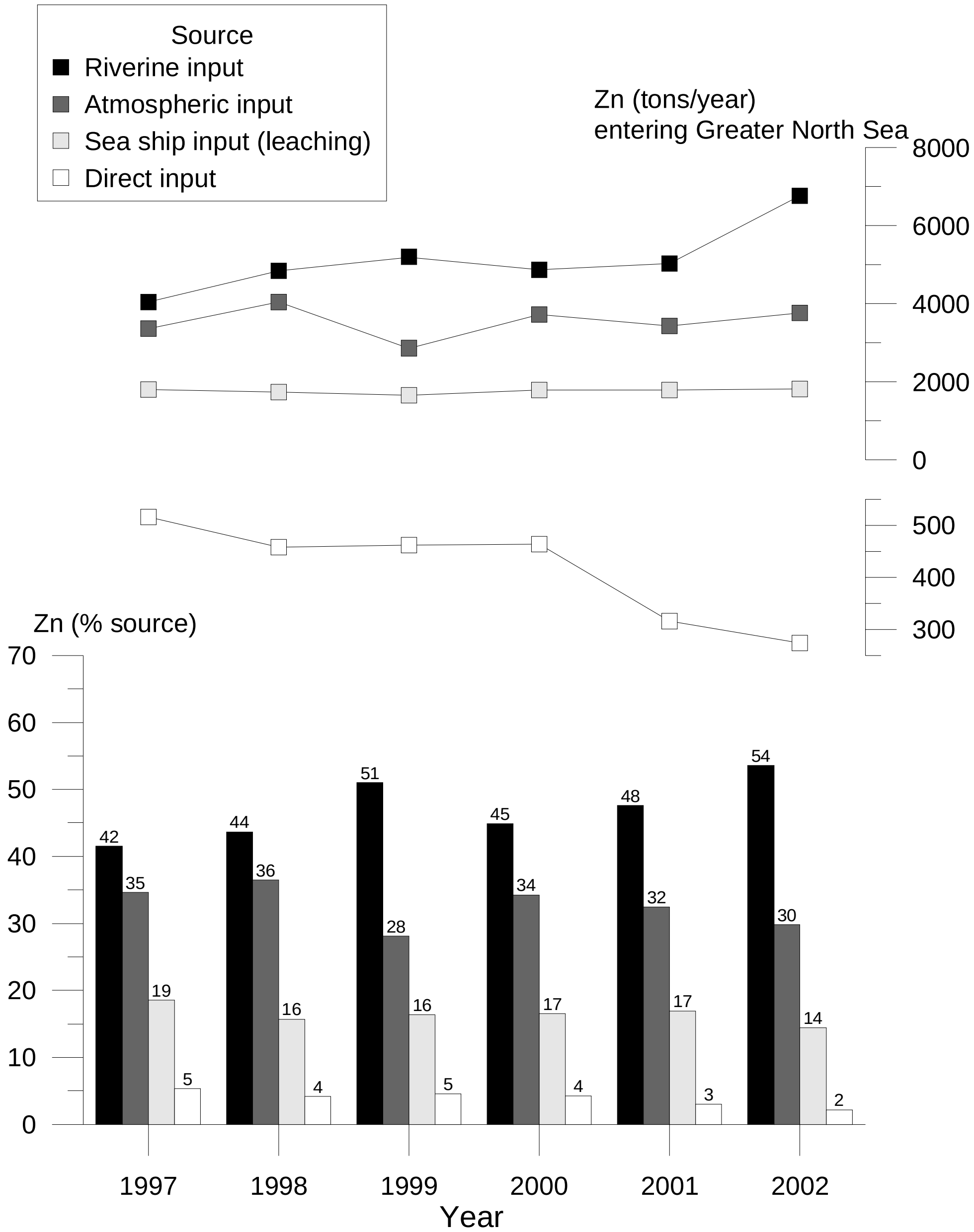

Figure 2. The input (both absolute and relative) of zinc from various sources to the Greater North Sea.

3.4.3 Cadmium

The inputs of cadmium to the Greater North Sea increase in the following order of sources (Figure 3):

Sea ship inputs (losses by leaching) < direct discharges < atmospheric inputs < riverine inputs

Approximately 1 to 2 % of all cadmium entering the Greater North Sea is due to losses of cadmium by leaching from ship anodes. The percentage of sea ship inputs of cadmium in the year 2002 equals the direct discharges of cadmium in 2002. Direct discharges of cadmium decreased between 1997 and 2003. No increase or decrease is observed for the riverine and atmospheric inputs of cadmium in this period.

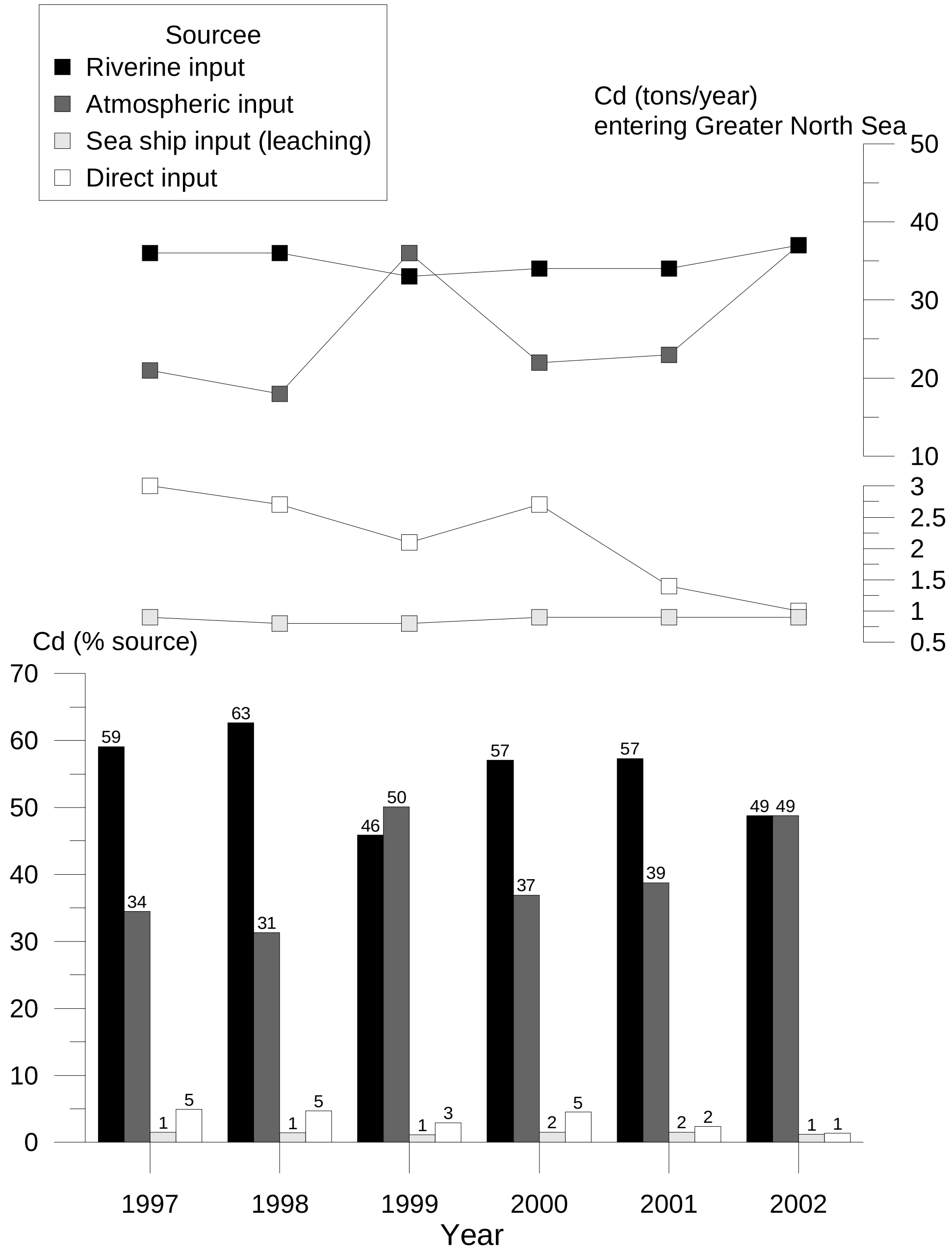

Figure 3. The inputs (both absolute and relative) of Cadmium from various sources to the Greater North Sea.

4. Discussion

4.1 A first estimate of losses of substances from ships to the Greater North Sea

Although the calculation of losses of copper, zinc, cadmium, TBT and biocides to the Greater North Sea by leaching from antifouling coatings and anodes is based on a number of assumptions and uncertainties, it gives a general idea about the possible extent of the associated total sea-ship-based inputs. The calculated input is most likely a conservative estimate of the total sea-ship-based losses since losses from recreational shipping and dumping of waste was not taken into account.

Recently, a report on losses of PAHs, copper and biocides from recreational shipping was published in the Netherlands (Oonk *et al.*, 2005). The estimate of quantities of biocides and copper released in 1985 – 2003 ranged from 1,5 to 12 tons per year for biocides and 14 to 79 tons per year for copper. These substances were released in all water bodies (both rivers and marine waters) in the Netherlands. Assuming that 10% of all copper and biocides lost by leaching from recreational ships in the Netherlands took place in waters of the NCS, the inputs of copper and biocides to the Greater North Sea due to losses by leaching from ships in general will increase by approximately 2,5% and 20%, respectively.

The above-mentioned example shows the impact additional information has on the 'real' input of hazardous substances or certain metals from shipping activities. The estimate of shipping activities can be further improved by improving the method used in this study to calculate losses by leaching from sea ships, thus addressing some of the uncertainties involved in the estimates. The following improvements are suggested:

- determine the total 'wet surface' for ships navigating each day the waters of the continental shelves of all Contracting Parties bordering the Greater North Sea together, based on SAMSON and the Lloyd's database. This should be done on an annual basis;
- collect data on fishing ships, offshore activity vessels, tugs and miscellaneous vessels that visited the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004 (the data are provided by EC Member States to Eurostat on a voluntary basis and the data sets held by Eurostat are, therefore, not complete). These data are often available in national databases (*e.g.* Statline and Statbank Denmark);
- get a better insight in the leaching rate of copper-containing antifouling coatings. The Leaching Factor for copper shows a large variation (1-101 µg/cm^2/day) (van Hattum *et al.*, 2002). Based on expertise available within the CEPE Antifouling Working Group, it was decided that the average Leaching Factor of copper is 50 µg/cm^2/day (CEPE, 1999), a value that agrees well with the leaching rates of ships longer than 25 m (37-101 µg/cm^2/day) (Lindgren *et al.*, 1998). Relatively low Leaching Factors are determined for ships longer than 12 meter (8-25 µg/cm^2/day) (Lindgren *et al.*, 1998) or unspecified ships (1-20 µg/cm^2/day) (Hare, 1993). Since most ships navigating the Greater North Sea are longer than 25 m, an average Leaching Factor for Cu of 50 µg/cm^2/day is justifiable;
- get a better understanding of the amount of ballast water being released to the Greater North Sea.

4.2 Comparison of losses calculated with different methods

Several other Contracting Parties also made estimates of the amount of hazardous substances and certain metals released to sea water as a result of leaching from antifouling coatings and anodes. Two methods have been used for quantifying these losses:

- estimation based on leaching rates, 'wet surface area' and shipping traffic (total distance sailed in inner waters). Method used in Denmark (ASMO 1998);
- estimation based on the amounts of antifouling products and anodes sold/consumed in a country. Method used by Denmark, Norway and Sweden (ASMO 1998 and Appendix A).

The first method best resembles the Dutch method. A comparison of the results for quantifying losses of substances from sea ships is listed in Table 8.

Table 8. Comparison of three methods used to estimate the losses of TBT, copper and zinc to the marine environment as a result of leaching from antifouling coatings and anodes of sea ships.

	Method 1 (Dutch)[#1]	**Method 2 (Danish)[#2]**	**Method 3 (products sold)**
TBT (tons/year)			
• Denmark (excluding ferries and passenger ships)	5,0-5,9 [#2]	0,6-4,9	4,8-5,4
• Norway	6-7	-	9-27,8
• Sweden	16-21	-	3,3-5,1
Cu (tons/year)			
• Norway	13-16	-	245-340
• Sweden	38-52	-	44,1-127,8
Zn (tons/year)			
• Norway	81-86	-	976-1 032

#1 Data source is http://epp.eurostat.cec.eu.int (number of all vessels visiting harbours of Contracting Party).
#2 Data source is http://www.statbank.dk (number of vessels visiting Danish harbours - no ferries and passenger ships). It should be noted that the estimated amount of TBT lost by leaching is determined for all vessels navigating waters of the Danish Continental Shelf, excluding ferries and passenger ships (ASMO 1998). However, the number of ferries and passenger ships that visit the harbours of Denmark in a year is relatively large compared with the cargo vessels. According to the database of Statbank Denmark, the number of cargo vessels that visit Danish harbours in a year varies between 27 000 and 32 000 (1997 and 2004, respectively) whereas the number of ferries and passenger ships varies between 515 000 and 560 000 in the same period. If these sea ships are taken into account, the amount of TBT that is lost by leaching from antifouling coatings would increase dramatically.

The estimated quantities of TBT lost by leaching from antifouling coatings of ships in the coastal waters of Denmark, calculated with the three methods, are in good agreement (same order of magnitude). The amounts of copper and zinc that enter the coastal waters of Norway and Sweden based on method 3 (products sold) is in general higher than the estimation based on method 1. Method 3, however, is most likely less precise than method 1, because not all antifouling paints sold are applied in the year they are sold and not all hazardous substances or metals in sold antifouling paints will end up in the marine environment due to leaching.

4.3 Is the loss of hazardous substances and metals by leaching from sea ships a relevant source?

Figures 1 – 3 show that losses by leaching from antifouling coatings and anodes contribute significantly to the input of copper and zinc to the Greater North Sea. Approximately 14 to 19 % of all copper and 14 to 19 % of all zinc entering the Greater North Sea are losses from antifouling coatings and ship anodes. This makes them more important than the direct discharges of copper and zinc and almost equally important as atmospheric deposition.

Estimated amounts of 122 to 135 tons of TBT and 4 to 5 tons of biocides enter the Greater North Sea due to losses by leaching from antifouling coatings. Since there is hardly any information on the inputs of TBT and biocides to the Greater North Sea from other sources (riverine and atmospheric inputs, and direct discharges), no comparison with other sources could be made. However, as a reply to a request for information, the Netherlands presented a document entitled ‘Emissions and Riverine input to the Convention Area of TBT compounds in the Netherlands’ to INPUT 1996 (cf. INPUT 96/11/3). The conclusions drawn in this document were that the main source of TBT is losses by leaching from sea ship hulls and that contributions from inland sources are negligible.

The application of tin-containing antifouling coatings on ships flying the flag of an EU Member State is forbidden since 1 July 2003 (Regulation (EC) No 782/2003). From 2008, tin-containing coatings are forbidden on all ships that visit EU harbours (application of a top-layer that prevents leaching is allowed). This will cause a major change in the input of TBT, copper and biocides to the marine environment. The input of TBT will most likely decrease dramatically, while the input of copper and biocides will increase, since sea ship hulls will be protected with other substances than TBT. Most likely this will increase the relative contribution of copper from sea ships as compared to other sources (Figure 1).

5. Conclusions

Estimating the losses of hazardous substances and certain metals by leaching from antifouling coatings and anodes used on ships is based on a number of factors. Uncertainties in these factors and in their underlying data cause uncertainties in the estimated losses of TBT, biocides, copper and zinc to the Greater North Sea. With these uncertainties in mind, the calculated quantities still give a first estimate of the magnitude of losses of these substances and metals to the Greater North Sea.

Based on the method used it is estimated that, between 1997 and 2002, each year 287 tons to 315 tons of copper entered the Greater North Sea due to losses by leaching from antifouling coatings and ship anodes. This is approximately 14 to 19% of all copper entering the Greater North Sea. This percentage is larger than that of direct discharges and equals the input of copper through atmospheric deposition in the year 2002. The inputs of copper to the Greater North Sea increase in the following order of sources:

Direct discharges < sea ship inputs (losses by leaching) < atmospheric inputs < riverine inputs

Based on the method used it is estimated that, between 1997 and 2002, each year 1 664 tons to 1 820 tons of zinc entered the Greater North Sea due to losses by leaching from ship anodes. This is approximately 14 to 19% of all zinc entering the Greater North Sea. This percentage is larger than the contribution of direct discharges. The inputs of zinc to the Greater North Sea increase in the following order of sources:

Direct discharges < sea ship inputs (losses by leaching) < atmospheric inputs < riverine inputs

Based on the method used it is estimated that, between 1997 and 2002, each year 0,8 tons to 0,9 tons of cadmium entered the Greater North Sea due to losses by leaching from ship anodes. This is approximately 1 to 2% of all cadmium entering the Greater North Sea. This percentage equals the input of cadmium from direct discharges in the year 2001 and 2002. The inputs of cadmium to the Greater North Sea increase in the following order of sources:

Sea ship inputs (losses by leaching) < direct discharges < atmospheric inputs < riverine inputs

The estimated total quantities of TBT lost each year by leaching from antifouling coatings of sea ships to the Greater North Sea ranges from 122 tons to 135 tons in the period 1997 – 2002. In the absence of relevant and useful data on other sources (direct discharges and riverine and atmospheric inputs), no comparison with inputs of TBT from other sources can be made.

The estimated total amount of biocides lost each year by leaching from antifouling coatings of sea ships to the Greater North Sea range from 4 tons to 5 tons in the period 1997 – 2002. In the absence of relevant and useful data on other sources (direct discharges and riverine and atmospheric inputs), no comparison with inputs of biocides from other sources can be made.

The estimated losses of TBT to waters of the continental shelf of Denmark from sea ships, as calculated in this study, agrees well with those calculated with the method used by Denmark (ASMO 1998). The quantities of certain metals (copper and zinc) entering the marine environment, estimated by Sweden and Norway, are in general higher than those calculated in this study. The calculation method used by Sweden and Norway is based on the amount of antifouling paints sold/consumed. This method is most likely less precise than the method used in this study, because not all antifouling paints sold are applied in the year that they are sold and not all hazardous substances and metals in sold antifouling paints will end up in the marine environment due to leaching.

With the mentioned uncertainties in mind, this document shows that the sea-based input of copper and zinc to the Greater North Sea is quite substantial (14 – 19%) and is expected to increase with the substitution of TBT as antifouling agent by copper-based paints. In future work, the estimation of losses of substances from antifouling coatings and ship anodes can be improved by:

- determining the total ‘wet surface’ for ships that daily navigate the continental shelves of all Contracting Parties bordering the Greater North Sea together, based on SAMSON and the Lloyd’s database. This should be done on an annual basis;
- collecting data on fishing ships, offshore activity vessels, tugs and miscellaneous vessels that visited the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004 (data are provided by EC Member States to Eurostat on a voluntary basis and the data sets held by Eurostat are, therefore, not complete). These data are often available in national databases (*e.g.* Statline and Statbank Denmark);
- getting a better insight in the leaching rate of copper-containing antifouling coatings;
- getting a better understanding of the amount of ballast water released to the Greater North Sea.

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Appendix A Information from Norway and Sweden on inputs of substances from sea ships to marine waters

1. Norway

1.1 TBT/TFT

1.1.1 Amounts in products

An overview of content in commercial products is given in Table A1. The table shows the trend from 1995 to 2003.

Table A1: Amount of tributyltin in products in 1995, 2002 and 2003

Source	1995 tonnes	2002 tonnes	2003 tonnes
Anti-fouling	27,8	18,4	9

1.1.2 Inputs to the environment of TBT/TFT from products

Table A2 shows the distribution of TBT/TFT from products to different parts of the Norwegian environment in 2003. As can be seen from Table A2 most of TBT/TFT ends up in water. TBT/TFT used on boats and ships on freshwater lakes and rivers are negligible compared to marine use.

Table A2: Inputs of TBT/TFT to the environment in 2003

Source	Total tonnes	Water tonnes	Soil tonnes	Waste tonnes
Anti-fouling	9	7,3	0,8	0,9

Table A3 shows the trend in inputs of TBT/TFT to water in the period 1995 – 2003.

Table A3: Inputs of TBT/TFT to water from anti-fouling in 1995, 2002 and 2003.

Source	1995 tonnes	2002 tonnes	2003 tonnes
Anti-fouling	25	14,9	7,3

1.1.3 Comments:

Anti-fouling makes up nearly 100% of Norwegian TBT/TFT inputs to the environment. For anti-fouling approximately 10% of the content in commercial products is disposed of as waste. Of the remaining 90%, 10% end up in soil when applying on ships hull as anti-fouling, 90% ends up in water.

1.2 Copper

An overview of content in commercial products is given in Table A4. The table shows the trend from 1995 to 2003.

Table A4: Amounts of Cu in anti-fouling sold in 1995, 2002 and 2003

Source	1995 tonnes	2002 tonnes	2003 tonnes
Anti-fouling	340	260	245

It is anticipated that inputs to sea equals the amount sold. So far Cu has been mostly used on smaller boats and not large ships. Maintenance of such boats is in near vicinity to the sea and therefore we calculate that all Cu used on boats ends up in the sea. From 2003 on the same factor for leakage of Cu as for TBT will be used.

1.3 Zinc

1.3.1 Amounts in products

An overview of the content of zinc in commercial products is given in Table A5.

Table A5: Amounts of zinc in products in 1990, 1995, 1996, 1997, 1998, 1999, 2000, 2001 and 2002

Source	**1995** (tonnes Zn)	**2001** (tonnes Zn)	**2002** (tonnes Zn)
Anodes	561	345	605
Anti-fouling, paint, etc.	415	652	427

Anti-fouling, primer, paint: Pure zinc (powder etc) and zinc oxide are used in anti-fouling, primer and paint as anti-corrosion and biocide.

Anodes: Anodes are used as anti-corrosion on ships hull, pipelines and other installations at sea.

1.3.2 Inputs of zinc to the environment

Table A6: Inputs of zinc from products in 2002

Source	**In products** (tonnes Zn)	**Emissions to air** (tonnes Zn)	**Inputs to water** (tonnes Zn)	**To soil** (tonnes Zn)	**Waste** (tonnes Zn)
Anodes	605	-	605	-	-
Anti-fouling, grunning, paints	427	-	-	43	NI

NI = no information

Table A7: Inputs of zinc to water in 1995 and 2002

Source	**1995** (tonnes Zn)	**2002** (tonnes Zn)
Anodes	561	605

Losses from anodes: Inputs to water is anticipated to be equal to amount in products (F_V=1).

Losses from anti-fouling, paints etc.: Paint with zinc is mostly used on huge steel constructions and ships as anti-corrosion. Loss of paint while applying is calculated to be 10%. Recipient for losses will mainly be soil (F_J=0,1).

2. Sweden

Figures on active substances in painting (antifouling) sold out total for Sweden are shown in Table A8.

Table A8: Amount of active substances (tons) in painting (antifouling) sold out total for Sweden

Substance	Amount of substances (tons) in painting (antifouling) sold out total				
	1999	**2000**	**2001**	**2002**	**2003**
Tributyltinmetakrylat	3,3	4,9	5,1	Forbidden	Forbidden
Copper (for antifouling)	44,1	59,2	67,8	92,2	127,8

Appendix B Example for quantifying losses (copper in 1997)

This is an example for calculating the losses of substances by leaching from ship coatings and anodes into the Greater North Sea using the losses of copper in 1997 to the Greater North Sea as example.

1. Losses by leaching from ship coatings

Equation 1

$$Cu_{leach-1997} = N_{ships} \times Surface_{wet} \times v_{leach-Cu} \times ap_{Cu} \times f \times rp_{Cu} \div 100{,}000{,}000$$

In which:

N_{ships} = number of sea ships visiting the harbours of the Greater North Sea in 1997
= 710 433 (table 2)

$Surface_{wet}$ = average 'wet ship surface' (m^2)
= 3 533

$v_{leach-Cu}$ = average Leaching Factor of Cu ($\mu g/cm^2/day$)
= 50

ap_{Cu} = application percentage of Cu
= 0,1

f = factor expressing the relation between the number of sea ships visiting the Dutch harbours each year and the number of sea ships navigating the waters of the Netherlands' Continental Shelf (NCS). This factor expresses the average number of days that a ship is navigating the waters of NCS (day).
= 1,5388

rp_{Cu} = reduction percentage of Cu due to regulation on the use of antifouling coatings and anodes
= 1

Thus:

Cu_{leach} = the quantities of Cu leached from sea ships (tons/y) in 1997 to the Greater North Sea
= 710 433×3 533×50×0,1×1,5388×1÷100 000 000
= **193 tons**

2. Losses by leaching from ship anodes

In 1997, 7,54 tons Cu was lost to waters of the NCS by leaching from ship anodes (Kuiper, 2003). This value was a.o. calculated based on the number of ships (45 511) visiting the Dutch harbours in 1997 (Table 2; source: Eurostat database).

The total number of ships visiting the harbours of the Greater North Sea in 1997 is 710 433 (Table 2; source: Eurostat database).

The losses of Cu in 1997 to the Greater North Sea by leaching from ship anodes are calculated as follows:

- number of ships visiting the harbours of the Greater North Sea in 1997 divided by the numbers of ships visiting the harbours of the NCS in 1997 multiplied by the amount of Cu (tons) lost to waters of the NCS by leaching from ship anodes in 1997.
- 710 433÷45 511×7,54 = **118 tons**

These calculations are performed under the assumptions mentioned in section 2.2.2.

3. Total losses by leaching from ship coatings and anodes

In 1997, the total losses of Cu to the Greater North Sea by leaching from ship coatings and anodes are the sum of **193 tons** and **118 tons**; this is **311 tons** (see Table 3).

Appendix C Eurostat data on sea ships visiting harbours of the Greater North Sea used for calculations

Table C1. Vessel types included in the calculations (source: Eurostat database).

VESSEL TYPE	VESSEL TYPE
CARGO	CARGO, NON-SPECIALIZED
CARGO	CARGO, SPECIALIZED
CARGO	CONTAINER
CARGO	DRY BULK
CARGO	DRY CARGO BARGE
CARGO	LIQUID BULK
CARGO	TUGS
PASSENGERS	CRUISE PASSENGER ONLY
PASSENGERS	PASSENGER
FISHING	FISHING
OFFSHORE ACTIVITIES	OFFSHORE ACTIVITIES
MISCELLANEOUS	MISCELLANEOUS
UNKNOWN	UNKNOWN

Table C2 Number and types (cargo, passenger, fishing, offshore, miscellaneous and unknown) of (registered) ships that visited the harbours of the Contracting Parties bordering the Greater North Sea between 1997 and 2004 (source: Eurostat database).

Country	Ships	1997	1998	1999	2000	2001	2002	2003	2004
Netherlands	Cargo	41 614	42 016	42 995	42 657	42 345	42 238	42 998	44 722
	Passenger	43	80	230	115	90	89	95	67
	Fishing	62	42	30	54	37	47	79	17
	Offshore	2 009	1 616	1 423	1 923	2 013	2 218	1 814	1 891
	Miscellaneous	1 783	1 476	1 393	1 299	1 435	1 247	1 229	1 058
	Unknown	-	-	-	-	-	-	-	-
	Total	**45 511**	**45 230**	**46 071**	**46 048**	**45 920**	**45 839**	**46 215**	**47 755**
Belgium	Cargo	18 607	19 352	18 350	21 979	21 706	21 661	20 344	22 364
	Passenger	118	32	48	49	75	39	57	55
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	-	-	-	-	-	-	-
	Miscellaneous	13 204	12 647	12 086	10 732	10 471	9 961	9 925	7 845
	Unknown	-	-	-	-	-	-	-	-
	Total	**31 929**	**32 031**	**30 484**	**32 760**	**32 252**	**31 661**	**30 326**	**30 264**
Germany	Cargo	-	-	-	55 712	55 260	55 347	54 832	60 397
	Passenger	-	-	-	9 097	12 114	12 701	13 079	24 885
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	-	-	5	1	1	-	-
	Miscellaneous	-	-	-	612	462	356	294	711
	Unknown	28 701	29 350	29 616	-	-	-	-	-
	Total	**28 701**	**29 350**	**29 616**	**65 426**	**67 837**	**68 405**	**68 205**	**85 993**
Sweden	Cargo	11 909	12 217	13 459	12 491	11 226	10 973	10 762	10 872
	Passenger	4 324	4 485	2 441	206	530	357	340	340
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	-	-	-	-	38	12	1
	Miscellaneous	-	-	-	-	-	-	-	-
	Unknown	-	-	-	-	-	-	-	-
	Total	**16 233**	**16 702**	**15 900**	**12 697**	**11 756**	**11 368**	**11 114**	**11 213**

Norway	Cargo	-	-	-	-	-	27 692	30 685	32 005
	Passenger	-	-	-	-	-	1 900	202	3 188
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	-	-	-	-	2 766	0	2 473
	Miscellaneous	-	-	-	-	-	-	-	-
	Unknown	-	-	-	-	-	-	-	-
	Total	**-**	**-**	**-**	**-**	**-**	**32 358**	**30 887**	**37 666**
Denmark	Cargo	386 169	362 661	331 239	316 310	313 381	335 444	334 796	340 521
	Passenger	12 972	13 105	14 403	13 973	10 120	9 870	9 512	8 891
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	-	-	-	-	-	-	-
	Miscellaneous	-	-	-	-	-	-	-	-
	Unknown	-	-	-	-	-	-	-	-
	Total	**399 141**	**375 766**	**345 642**	**330 283**	**323 501**	**345 314**	**344 308**	**349 412**
France	Cargo	-	7 571	8 442	39 225	42 732	44 868	44 430	44 208
	Passenger	-	4 800	5 603	5 408	4 450	4 424	5 849	3 678
	Fishing	-	-	-	-	-	-	-	-
	Offshore	-	4	3	3	10	8	8	5
	Miscellaneous	-	73	662	1 394	884	975	1 645	2 223
	Unknown	-	-	-	-	-	-	-	-
	Total	**-**	**12 448**	**14 710**	**46 030**	**48 076**	**50 275**	**51 932**	**50 114**
UK	Cargo	-	-	-	130 029	136 811	134 717	130 391	124 861
	Passenger	-	-	-	331	194	174	245	140
	Fishing	-	-	-	68	106	66	48	0
	Offshore	-	-	-	5 389	5 789	5 852	5 844	6 161
	Miscellaneous	-	-	-	3 255	3 639	3 406	3 560	3 289
	Unknown	-	-	-	697	576	342	967	1 564
	Total	**-**	**-**	**-**	**139 769**	**147 115**	**144 557**	**141 055**	**136 015**

Table C3 Number of ports included harbours of each Contracting Parties bordering the Greater North Sea between 1997 and 2004 (source: Eurostat database).

	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
BE Belgium	4	4	4	4	4	4	4	4
DK Denmark	48	47	43	43	44	47	46	49
DE Germany	10	10	10	18	18	18	18	31
FR France	0	3	5	11	11	11	11	11
NL Netherlands	14	14	14	14	14	14	14	14
SE Sweden	7	7	7	7	7	7	7	7
GB United Kingdom	0	0	0	40	42	41	40	40
NO Norway	0	0	0	0	0	24	24	25
Total	83	85	83	137	140	166	164	181

Appendix D Overview of inputs of selected hazardous substances and metals to the Greater North Sea from various sources

Table D1: **COPPER**: Overview of the inputs of copper (Cu) from various sources to the Greater North Sea between 1990 and 2002

Parameter	Source	Estimate	1990[#1]	1996[#1]	1997[#2]	1998[#2]	1999[#3]	2000[#4]	2001[#4]	2002[#4]
Cu (ton/y)	Direct discharge	Average *(Range)*	305 *(300-310)*	160 *(160)*	158 *(157-158)*	144 *(144-145)*	144 *(144-145)*	132 *(131-132)*	102 *(101-102)*	86 *(85-86)*
Cu (ton/y)	Atmospheric inputs	Average	417	440	372	405	451	425	366	309
Cu (ton/y)	Riverine inputs	Average *(Range)*	1 250 *(1 200-1 300)*	950 *(900-1 000)*	783 *(764-802)*	1 038 *(1 029-1 047)*	1 136 *(1 132-1 141)*	1 102 *(1 095-1 109)*	1 144 *(1 138-1 150)*	1 252 *(1 244-1 259)*
Cu (ton/y)	Ship coatings	Average	-	-	193	187	179	192	193	198
Cu (ton/y)	Ship anodes (electric antifouling)	Average	-	-	118	114	108	116	115	117
Total		**Average**	**-**	**-**	**1 624**	**1 888**	**2 018**	**1 967**	**1 920**	**1 962**
Ships/total (%)		**Average**	-	-	**19**	**16**	**14**	**16**	**16**	**16**

#1 Riverine inputs and direct discharges after OSPAR (2000); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#2 Riverine inputs and direct discharges after OSPAR (2001a); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#3 Riverine inputs and direct discharges after OSPAR (2001b); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#4 Riverine inputs and direct discharges after OSPAR (2004); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report

Table D2: **ZINC**: Overview of the input of various sources of zinc (Zn) to the Greater North Sea between 1990 and 2002

Parameter	Source	Estimate	1990#1	1996#2	1997#2	1998#2	1999#3	2000#4	2001#4	2002#4
Zn (ton/y)	Direct discharge	Average *(Range)*	-	654 *(651-656)*	516 *(513-518)*	458 *(455-460)*	462 *(459-464)*	464 *(462-467)*	316 *(313-318)*	274 *(271-276)*
Zn (ton/y)	Atmospheric	Average	3 436	4 901	3 362	4 047	2 862	3 721	3 429	3 760
Zn (ton/y)	Riverine	Average *(Range)*	-	5 020 *(4 960-5 080)*	4 038 *(3 916-4 160)*	4 845 *(4 695-4 995)*	5 195 *(5 117-5 273)*	4 875 *(4 848-4 902)*	5 026 *(5 002-5 049)*	6 764 *(6 713-6 815)*
Zn (ton/y)	Ship anodes (exterior)	Average	-	-	1 522	1 471	1 406	1 519	1 511	1 538
Zn (ton/y)	Ship anodes (ballast tanks)	Average	-	-	280	271	258	278	277	282
Total		**Average**	**-**	**-**	**9 718**	**11 092**	**10 183**	**10 857**	**10 559**	**12 618**
Ships/Total (%)		**Average**	-	-	**19**	**16**	**16**	**17**	**17**	**14**

#1 Riverine inputs and direct discharges after OSPAR (2000); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#2 Riverine inputs and direct discharges after OSPAR (2001a); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#3 Riverine inputs and direct discharges after OSPAR (2001b); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report
#4 Riverine inputs and direct discharges after OSPAR (2004); Atmospheric inputs after OSPAR (2005a); Shipping based inputs estimated in this report

Table D3: **CADMIUM**: Overview of the input of various sources of cadmium (Cd) to the Greater North Sea between 1990 and 2002

Parameter	Source	Estimate	1990#5	1996#5	1997#5	1998#5	1999#5	2000#5	2001#5	2002#5
Cd (ton/y)	Direct discharge	Average	9,3	2,9	3,0	2,7	2,1	2,7	1,4	1,0
Cd (ton/y)	Atmospheric	Average	39	21	21	18	36	22	23	37
Cd (ton/y)	Adjusted riverine	Average	67	47	36	36	33	34	34	37
Cd (ton/y)	Ship anodes (exterior)	Average	-	-	0,8	0,7	0,7	0,8	0,8	0,8
Cd (ton/y)	Ship anodes (ballast tanks)	Average	-	-	0,1	0,1	0,1	0,1	0,1	0,1
Total		**Average**	**-**	**-**	**60,9**	**57,5**	**71,9**	**59,6**	**60,7**	**75,9**
Ships/total (%)			**-**	**-**	**1,5**	**1,4**	**1,1**	**1,5**	**1,5**	**1,2**

#5 Adjusted riverine inputs and direct discharges after OSPAR (2005b); atmospheric inputs after OSPAR (2005a); shipping based inputs estimated in this report.

Table D4 **TBT**: Overview of the input of various sources of TBT to the Greater North Sea between 1990 and 2002

Parameter	Source	Estimate	1990#6	1996	1997	1998	1999	2000	2001	2002
TBT (ton/y)	Direct discharge	Average				No data				
TBT (ton/y)	Atmospheric	Average				No data				
TBT (ton/y)	Riverine	Average				No data				
TBT (ton/y)	Ship coatings	Average	Denmark 0,6-4,9 UK 6	-	131	127	122	131	131	135
Total		**Average**			**131**	**127**	**122**	**131**	**131**	**135**
Ships/total (%)		**Average**			**100**	**100**	**100**	**100**	**100**	**100**

#6 After ASMO (1998)

Table D5: **BIOCIDES**: Overview of the input of various sources of biocides to the Greater North Sea between 1990 and 2002

Parameter	Source	Estimate	1990	1996	1997	1998	1999	2000	2001	2002
Biocides (ton/y)	Direct discharge	Average				No data				
Biocides (ton/y)	Atmospheric	Average				No data				
Biocides (ton/y)	Riverine	Average				No data				
Biocides (ton/y)	Ship coatings	Average	-	-	5	5	4	5	5	5
Total		**Average**			**5**	**5**	**4**	**5**	**5**	**5**
Ships/total (%)		**Average**			**100**	**100**	**100**	**100**	**100**	**100**