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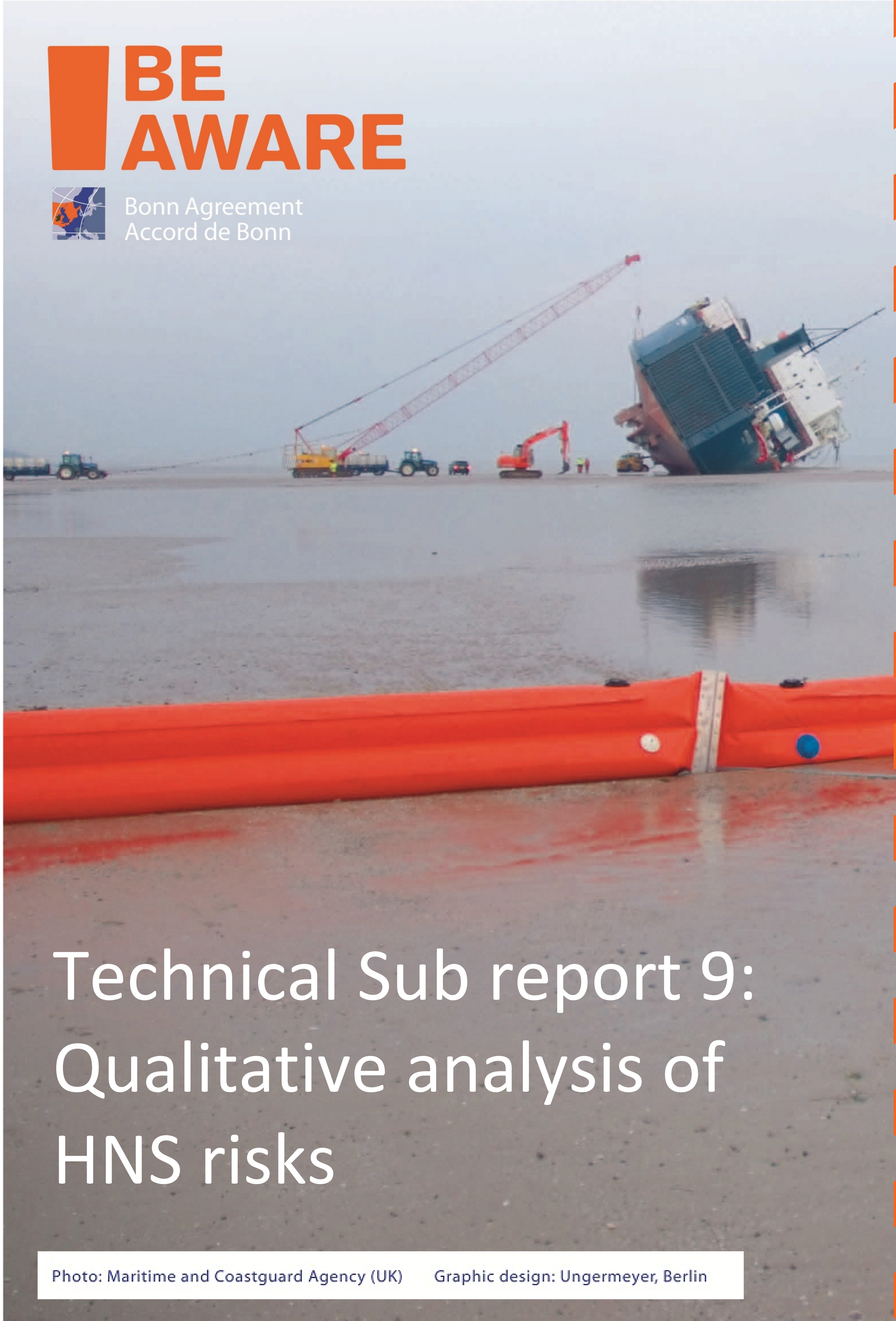

Technical Sub report 9: Qualitative analysis of HNS risks

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MARIN

Bonn Agreement
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The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. With the ever-increasing competition for space there may come an increased risk of accidents that could result in marine pollution.

Currently the area has no overall risk assessment for marine pollution; risk is mapped with a variety of national risk assessments which are undertaken with differing methodologies; thus reducing comparability.

The BE-AWARE project is therefore undertaking the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios.

The project outcomes will contribute to improving disaster prevention by allowing North Sea States to better focus their resources on areas of high risk.

The project is a two year initiative (2012-2014), co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway.

Contents

Executive Summary

This report describes the analyses of HNS risks for the Bonn Agreement area. Within the BE-AWARE project it was decided to focus on a qualitative analysis for HNS rather than undertaking a quantitative approach as was taken for oil. This was for several reasons:

- There is less information available on HNS shipments compared to oil shipments mainly because HNS is a more complex subject to map or monitor/track;
- The environmental impact of a HNS spill at sea can be different for every type of substance transported. There is no methodology available that includes these effects in a large area-based risk assessment such as for the greater North Sea;
- Chemical tankers can carry several types of substances. No extensive mapping/statistics are available at this stage related to the transport of different HNS types by tankers in the EU area.

In order to get an impression of the HNS transported in detail data was requested from the major ports in the Bonn Agreement area. Eventually data were only received from the ports of Rotterdam and Antwerp at the level of detail required for in-depth analysis. The information from the port of Rotterdam is limited to bulk (oil and HNS) and the information from the Port of Antwerp contains bulk (no oil) and packed goods, i.e. information from containers.

The methodology followed in this task can be divided into three steps: First, an overview was given of three methods of classifying dangerous goods (HNS). Second, an analysis was made of the data received from Rotterdam and Antwerp. An overview was made of the 100 most transported substances and a hazard classification had been made of the substances handled in the port. In the third step the databases from Rotterdam and Antwerp were combined with the SAMSON accident database for the BE-AWARE area. With this database an estimate could be made of the involvement of ships carrying HNS in collisions. The analyses have been made for two methods of classification and also the involvement of chemical tankers in a collision was estimated.

The conclusions in this study can be divided into three categories:

- Analyses of the HNS handled in Rotterdam and Antwerp;
- Approximation of the probability that HNS is involved in collisions;
- The geographical distribution of HNS involved in collisions.

Analyses of the HNS handled in Rotterdam and Antwerp

The database received from Rotterdam only contained data on substances handled in bulk. The database received from Antwerp included both packed and bulk goods. Within this study it was possible to make a comparison between Rotterdam and Antwerp of the substances handled in bulk and a comparison of the substances handled in bulk and packed within the port of Antwerp.

Comparison for bulk goods

In table 0-1 a comparison is made between the goods handled in bulk in Rotterdam and Antwerp. Both databases contain HNS, but also non dangerous goods. When the percentage of substances classified as International Maritime Dangerous Goods code (IMDG) 1-9 are compared for the two ports the percentage for Rotterdam is slightly smaller than for Antwerp.

Goods transported in bulk	Rotterdam				Antwerp				Comparison
	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Rotterdam/ Antwerp
Total (HNS + harmless substances)	14277473	100.00%	5487	2602	31683760	100.00%	12408	2553	45%
Total IMDG 1-9	10438155	73.11%	3566	2927	24900774	78.59%	10541	2362	42%
Total ACROPOL	562080	3.94%	275	2044	2107883	6.65%	257	8202	27%
Total GESAMP	2579	0.02%	18	143	1085	0.00%	7	155	238%

Table 0-1: Comparison of HNS transported in bulk to Rotterdam and Antwerp

In the last column the data for Rotterdam and Antwerp were compared. The amount of HNS handled in bulk in Antwerp is approximately a factor two (2.2) larger than in Rotterdam. When the percentage of the total amount that was classified as IMDG 1-9 is compared for the two ports the percentage for Rotterdam (73%) is slightly smaller than for Antwerp (78%).

In Antwerp the variation in the IMDG classification of the substances is much larger than for Rotterdam, see Table 4-2 for Antwerp and Table 3-2 for Rotterdam. For Antwerp the substances are divided over 26 IMDG classes and for Rotterdam they are divided over 14 classes. However, many classes give a relatively small contribution. The figure 0-1 shows a comparison between Antwerp and Rotterdam for those IMDG classes that contribute more than 1% to the total.

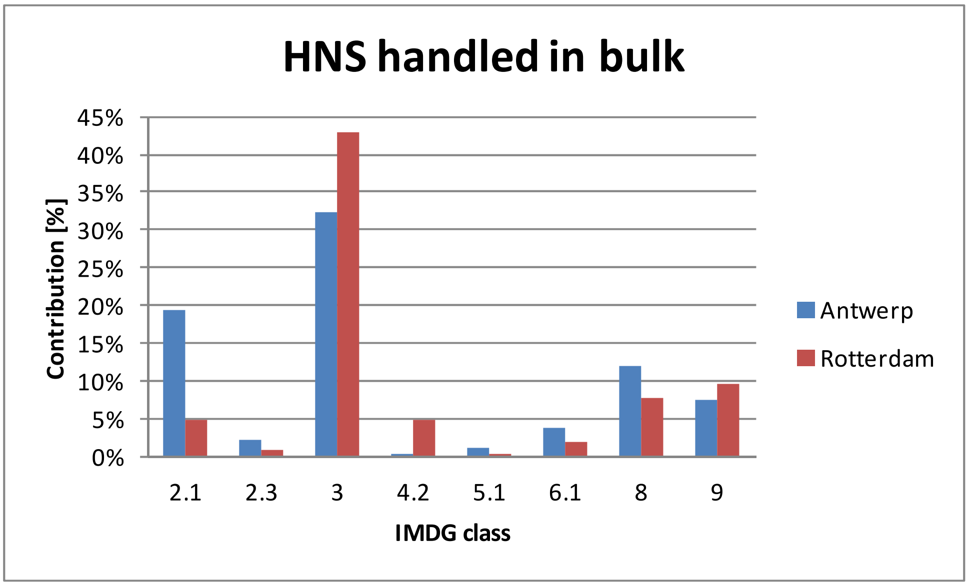


Figure 0-1: IMDG classification of bulk cargo for Rotterdam and Antwerp (contribution larger than 1%) [1]

Comparing the amounts handled from the Top 20 ARCOPOL (Atlantic Regions' Coastal Pollution Response) project list of substances dangerous to human health one can conclude that Antwerp handles almost 5 times more Top 20 ARCOPOL classified substances in bulk than Rotterdam. For GESAMP (Joint Group of Experts on Scientific Aspects of Marine Pollution) it is the other way around with Rotterdam handling more. But it should be noted that the amounts are extremely small in both ports so it is unlikely that these comparisons are of key interest.

Comparison of bulk and packed goods

This comparison can only be made for Antwerp. In table 0-2 the amount of cargo handled as packed or as bulk is summarized.

[1] The IMDG classes referred to in figure 0-1 are: 2.1: flammable gases; 2.3: toxic gases; 3: flammable liquids; 4.2: substances liable to spontaneously combust; 5.1: oxidizing substances; 6.1: toxic substances; 8: corrosive substances; 9: miscellaneous dangerous substances and articles

Table 0-2: Comparison of HNS transported in bulk and packed to Antwerp

Antwerp	Packed				Bulk				Comparison
	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Packed/Bulk
Total (HNS + harmless substances)	13198301	100.00%	167721	79	31683760	100.00%	12408	2553	42%
IMDG 1-9	13198301	100.00%	167721	79	24900774	78.59%	10541	2362	53%
Arcopol	770679	5.84%	3166	243.4	2107883	6.65%	257	8202	37%
GESAMP	6846	0.05%	416	16.5	1085	0.00%	7	155	631%

From this table it can be concluded that in the port of Antwerp a considerable amount of HNS cargo is handled as packed goods. The amount of packed goods was approximately 50% of the amount of bulk. This is a large amount as parcel sizes are much smaller.

Comparing the IMDG classification for packed and bulk it can be concluded that a larger variation of goods is transported as parcel (32 IMDG classes) than in bulk (26 IMDG classes). For both bulk and parcels a number of classes contain very small amounts of cargo, see also Table 4-2. Figure 0-2 gives an overview of those IMDG classes that contribute more than 1 per-cent to the total.

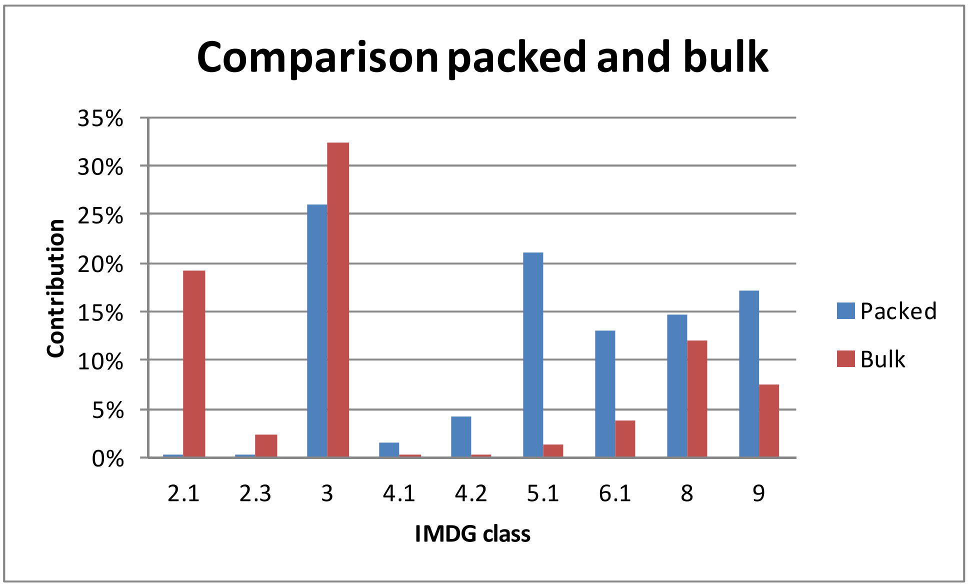


Figure 0-2: Comparison of the IMDG classification of cargo transported packed and as bulk (contribution larger than 1%)

The TOP 20 ARCOPOL substances are handled more often as bulk cargo. But approximately 6% of the HNS handled are from the TOP 20 ARCOPOL list both for packed and bulk.

The result found for substances from the Top 100 GESAMP list is of special interest. The GESAMP list has been set-up to rank HNS transported in bulk. When the Top 100 GESAMP list is used to analyse the most dangerous goods transported as packed goods, dangerous substances identified as marine pollutants under IMDG that are normally transported as packed goods are not fully included in the analysis. However, as most GESAMP substances in the port of Antwerp are handled as packed goods this can be seen as an indicator that the most dangerous substances are probably handled as packed goods.

Approximation of the probability that HNS is involved in collisions

For the Bonn Agreement area an analysis has been made of the probability that HNS is involved in a collision on the basis of data from Antwerp and Rotterdam.

The result of this analysis is summarised in table 0-3.

Table 0-3 Amount of HNS cargo involved in collisions

HNS transported in bulk			
On basis of Rotterdam data	Amount [t]	Shipments involved in collisions, per year	Vessels involved in collisions, Per year
HNS and harmless substances	2916	4.00	1.45
HNS (IMDG classes 1-9)	2213	3.39	*1.23*
Chemical tankers I and II	3940	0.78	*0.28*
Chemical tankers I and II, (IMDG classes 1-9)	2688	0.33	*0.12*
TOP 20 ARCOPOL	89	0.14	*0.05*
On basis of Antwerp data			
HNS and harmless substances	1994	0.60	0.36
HNS (IMDG classes 1-9)	1414	0.52	*0.32*
HNS transported as packed goods (based on Antwerp data)			
Packed goods in IMDG classes 1-9	844	4.15	0.82

This table presents for various cargo classifications the predicted amount of (HNS) cargo involved in a collision per year, the predicted number of shipments involved in a collision per year and an estimate of the number vessels involved in collisions per year. There can be more than one shipment of a vessel. It should be noted that these figures are very indicative approximations as these are based on the datasets for Rotterdam and Antwerp only. Furthermore these figures only give a first, rough approximation of the number of incidents. It gives no indication of the amount of substances spilt.

From the table the following can be concluded (on basis of the data from Rotterdam):

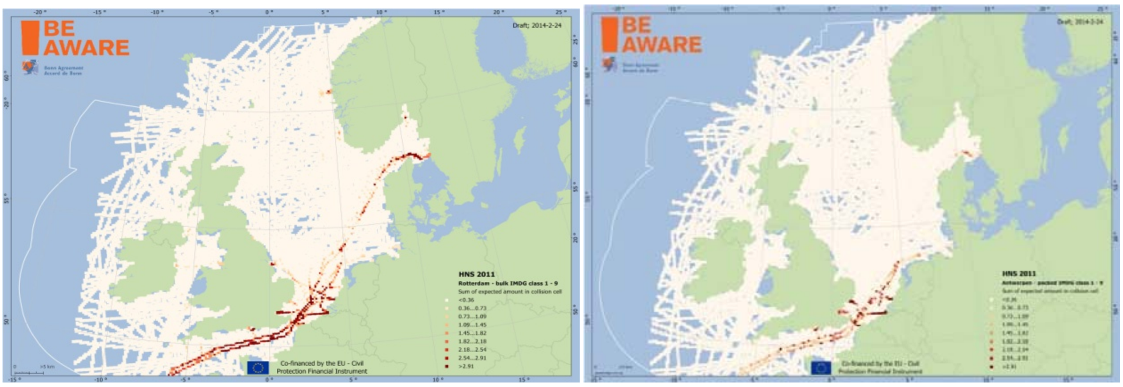
- From the 10 collisions that occur every year in the Bonn Agreement area one collision will include at least one vessel that carries substances classified as IMDG 1-9. Approximately 2200 tonnes of HNS will be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) will include a chemical tanker of class I or II. Per year approximately 3000 tonnes of HNS will be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) will include a vessel that carries substances from the Top 20 ARCOPOL list. Per year approximately 90 tonnes Arcopol HNS will be involved.
- The approximation based on the Antwerp data is somewhat lower than found on the basis of the Rotterdam data.

For HNS transported as packed goods the following can be concluded:

- It is estimated that there will be 0.8 collisions per year that involve a vessel with HNS on board;
- The total amount of HNS involved in a collision is 843 tonnes per year, which would include 4 different HNS shipments.

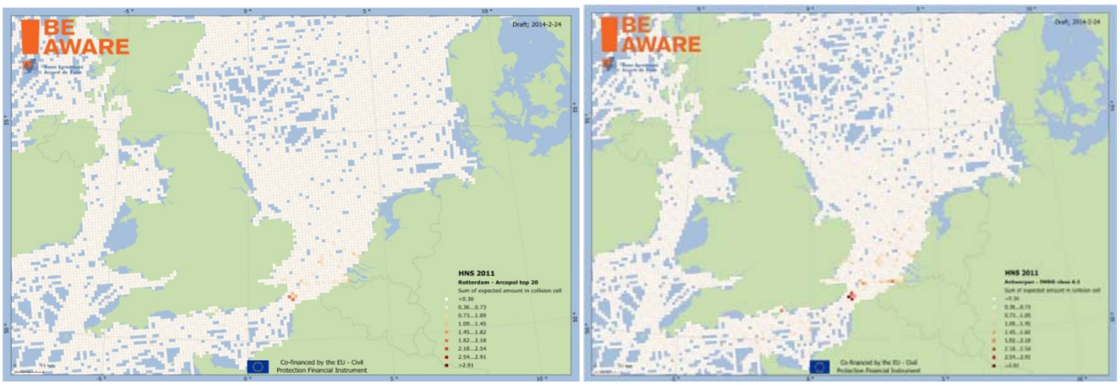
The geographical distribution of HNS involved in collisions

For both packed goods and bulk goods the geographical distribution of HNS in collisions has been determined. For the geographical distribution the results as described in section 7.2 have been used. These results are based on the HNS data received from the ports of Antwerp and Rotterdam only. Below a result is presented for a wide range of substances (IMDG 1-9) and more specific (harmful), ACROPOL and IMDG 6.1[2]. Please note that larger versions of these figures are included in Annex 1.



IMDG 1-9: left involved in collision as bulk, right as packed goods (containers)

It should be noted that although based on data from Rotterdam, risk concentration are found at Antwerp, Hull, Mongstad, Oslo and Southampton. For packed goods, based on data from Antwerp, contributions are found at Rotterdam, Oslo, Southampton, London and Felixstowe.



Left Top 20 ARCOPOL substances transported in bulk involved in collisions, right IMDG 6.1 transported as packed goods involved in collisions

For goods from the Top 20 ARCOPOL list transported in bulk, concentrations of risk are found on the southern North Sea but also in ports such as Southampton, Rotterdam, Western Scheldt and the approach to London.

For packed goods IMDG 6.1 has been further analysed. Higher risk concentrations are found, amongst others, in the ports of Southampton, London.

The ports of Rotterdam and Antwerp are among the biggest ports in Europe and in the world. It is clear that a large share of the transported HNS in the North Sea would at one point be sailing in and out of one of these ports. However there are local trade patterns of HNS that are not captured by the analysis in this report because ships that carry HNS sail between local ports only, or because ships sail from a sea area outside the North Sea and directly to their destination i.e. without calling at Rotterdam or Antwerp. As a consequence some local risk areas will not have been identified on the

[2] toxic substances

above risk maps. HNS substances used locally for specialized industries could be a considerable risk locally but their quantity would be small compared to the quantities handled in the two ports used for reference in this report. HNS substances transported in and out of oil rigs can be an example of substances transported locally.

1. Introduction

The main objective of the BE-AWARE project is to conduct an area-wide risk assessment in the spillage of oil and Hazardous and Noxious Substances (HNS).

Within the BE-AWARE project it was not possible to calculate the risks of HNS transport in the same quantitative detail as for oil, because of the following reasons:

- There is less information available on HNS shipments compared to oil shipments mainly because HNS is a more complex subject to map or monitor/track;
- The environmental impact of a HNS spill at sea can be different for every type of substance transported, and there is no methodology available that includes these effects in a large area based risk assessment such as for the greater North Sea;
- Chemical tankers can carry several types of substances. No extensive mapping/statistics are available at this stage related to the transport of different HNS types by tankers in the EU area.

Because of the above mentioned reasons and taking into account the fact that the spill frequencies of HNS are very low compared to oil spill frequencies this study does not include a quantitative HNS spill risk assessment. The analysis had the following objectives:

- Assessment of hot-spot areas with respect to the risk caused by ships carrying HNS by qualitative analysis;
- Identify possible methodologies for future quantitative risk assessments;
- Identify areas requiring further research.

The focus of the analysis executed in this study was on HNS transported in bulk. However, also an analysis of HNS as packed good has been executed. There is a tendency to focus on those substances that are transported in large quantities. However, for some types of HNS the environmental impact can be large even for a very small amount (i.e. one or two containers, as in the case of the Sherbro, http://www.cedre.fr/en/spill/sherbro/sherbro.php).

Report structure

This report is divided into the following sections:

Section 2, describes the approach of the study. An overview is given of three different classifications of HNS. Furthermore the method used to estimate the amount of HNS involved in collisions is described.

Sections 3 and 4 give an overview of the HNS handled in Rotterdam and Antwerp.

Section 5 gives an overview of the qualitative risk assessment.

Section 6 describes future work on HNS

Section 7: Conclusions

Sections 8 and 9: References and Glossary

Annexes 1-4

2. Approach

2.1 Classification of HNS

The difficulty of HNS is that the danger or impact of substances can differ significantly. Some substances can be extremely polluting, others can be poisonous or flammable. Furthermore the characteristics of substances might change due to contact with air, water, fire or other substances carried on board. The wide range of characteristics and dangers make it difficult to use one single form of classification. In this report we used three different types of classification of HNS. These are:

- The IMDG code;
- The GESAMP list;
- The ARCOPOL list.

All three will be shortly discussed here.

2.1.1 Short description of the IMDG code

IMDG code: Resolution MSC.328 (90)-Adoption of amendments to the International Maritime Dangerous Goods (IMDG) code (Amendment 36-12).

Classification

For the purposes of this Code, it has been necessary to classify dangerous goods in different classes, to subdivide a number of these classes and to define and describe characteristics and properties of the substances, materials and articles which would fall within each class or division. Moreover, in accordance with the criteria for the selection of marine pollutants for the purposes of Annex III of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), a number of dangerous substances in the various classes have also been identified as substances harmful to the marine environment (Marine Pollutants).

Substances (including mixtures and solutions) and articles subject to the provisions of this Code are assigned to one of the classes 1–9 according to the hazard or the most predominant of the hazards they present. Some of these classes are subdivided. These classes or divisions are as listed below:

Class 1: Explosives
Division 1.1: substances and articles which have a mass explosion hazard
Division 1.2: substances and articles which have a projection hazard but not a mass explosion hazard
Division 1.3: substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
Division 1.4: substances and articles which present no significant hazard
Division 1.5: very insensitive substances which have a mass explosion hazard
Division 1.6: extremely insensitive articles which do not have a mass explosion hazard

Class 2: Gases
Class 2.1: flammable gases
Class 2.2: non-flammable, non-toxic gases
Class 2.3: toxic gases

Class 3: Flammable liquids

Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases
Class 4.1: flammable solids, self-reactive substances and solid desensitized explosives
Class 4.2: substances liable to spontaneous combustion
Class 4.3: substances which, in contact with water, emit flammable gases

Class 5: Oxidizing substances and organic peroxides
Class 5.1: oxidizing substances
Class 5.2: organic peroxides

Class 6: Toxic and infectious substances
Class 6.1: toxic substances
Class 6.2: infectious substances

Class 7: Radioactive material

Class 8: Corrosive substances

Class 9: Miscellaneous dangerous substances and articles

The advantage of this code is that all dangerous substances have an IMDG classification. For substances consisting of a mixture of different substances the most dangerous substances in general will determine the classification. For the classification of mixtures a table exists that indicates the priority in the classification.

To make a coupling between the data received from the ports of Rotterdam and Antwerp it was necessary to prepare a database which contains the name of the substances, the IMDG code and the UN number of the substance. The resulting database of substances contains approximately 4400 entries.

2.1.2 Top 100 GESAMP list

The IMDG code gives an insight into the type of hazard related to the specific substance. However, it must be realised that within a class the hazard level can differ significantly. For this reason we also tried to identify the most dangerous substances transported. For this analysis we used the information from an EU project: HASREP, Response to harmful substances spilled at sea. From this project we used the report on Task 1: Monitoring of the flow of chemicals transported by sea in bulk and in package form.

In section 3.2 of this report it is stated: The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) formed by experts from 8 United Nations institutions, has also elaborated a very comprehensive list of dangerous substances on the base of 5 hazard profiles. The report contains a table with the top 100 most harmful substances extracted from the GESAMP list.

It is important to note that the GESAMP working group concentrated on substances that are transported in bulk. This means that dangerous substances transported as packed goods in small quantities are not included in this list. This makes this list not applicable for the analysis of packed goods.

In the next table this GESAMP classification is presented.

Table 2-1 Criteria used for the GESAMP classification

Column	Title	Hazard	Comment
A	Bioaccumulation and tainting	♦ bioaccumulation in fish and shellfish ♦ tainting of seafood	bioaccumulation to "significant extent", with attendant harm to the organism
B	Damage to living resources	aquatic toxicity to fish and crustaceans	measured in appropriate aquatic ecotoxicity tests
C	Hazard to human health: ingestion of water containing the chemical	acute oral toxicity to humans	measured in appropriate tests with laboratory animals
D	Risk to human health by skin and eye contact or inhalation	irritation or injury to the skin, mucous membranes, or eyes and inhalation hazard	measured in appropriate tests with laboratory animals, or from human experience
E	Reduction of amenities	♦ objectionable slicks ♦ presence of poisonous, irritant or foul smelling substances ♦ impairment of scenic value ♦ drums or packages	amenities meant to mean all aspects of recreational use; this column was used to provide guidance to local authorities regarding the closure of beaches
Remarks		♦ "Unusual" hazards to fishing or navigation etc. ♦ Carcinogenicity ♦ Other adverse health effects	all other relevant hazards and explanatory remarks

An example of the classification of the most hazardous substances from this list is shown below. The complete list is included in the HASREP report.

Table 2-2 First 20 substances from the top 100 GESAMP list

GESAMP-Name	UN-number	A	B	C	D	E
Endosulphan	2761	+	5	4	II	XXX
Endrin (ISO)	2761	+	5	4	II	XXX
Fonofos (ISO)	2903	+	5	4	II	XXX
Terbufos (ISO)	2783	+	5	4	II	XXX
Aldrin (ISO)	2761	+	5	3	II	XXX
Camphechlor	2761	+	5	3	II	XXX
Carbophenothion	3018	+	5	3	II	XXX
Chlordane (ISO)	2762	+	5	3	II	XXX
Dieldrin (ISO)	2761	+	5	3	II	XXX
EPN (JMAF)	2783	+	5	3	II	XXX
Ethion (ISO)	3018	+	5	3	II	XXX
Fenitrothion (ISO)	3018	+	5	3	II	XXX
Fentin acetate (ISO)	2786	+	5	3	II	XXX
Heptachlor	2761	+	5	3	II	XXX
Lindane (ISO)	2761	+	5	3	II	XXX
Organotin compounds (N.O.S.)	3146	+	5	3	II	XXX
Phosphamidon (ISO)	3018	+	5	3	II	XXX
Tributyl tin compounds (See also individual compounds)		+	5	3	II	XXX
Coumaphos (ISO)	2783	+	5	3	I	XXX
Fenpropathrin (ISO)		+	5	3	I	XX
Cadmium compounds (N.O.S.)		+	5	2	II	XXX
Chlorpyrifos (ISO)	2783	+	5	2	II	XX
DDT (ISO)	2761	+	5	2	II	XXX
Diazinon (ISO)	2783	+	5	2	II	XXX
Esfenvalerate		+	5	2	II	XXX
Fenthion (ISO)	3017	+	5	2	II	XXX
Isoxathion (ISO)		+	5	2	II	XXX
Tributyl tin acetate		+	5	2	II	XXX
Tributyl tin chloride	2788	+	5	2	II	XXX
Tributyl tin oxide	3020	+	5	2	II	XXX
Cyhexatin (ISO)		+	5	2	I	XX
Cypermethrin (ISO)	2902	+	5	2	I	XX
Dichlofenthion	3018	+	5	2	I	XX
Phenthoate (ISO)	3018	+	5	2	I	XX
Phosalone (ISO)	2783	+	5	2	I	XX
Fenbutatin oxide (ISO)	2787	+	5	1	II	XX
Cadmium cyanide	2570	+	5	-	I	XX

2.1.3 Top 20 ARCOPOL list

ARCOPOL stands for: The Atlantic Regions' Coastal Pollution Response. For the information regarding the Arcopolplus project we refer to the Activity 3 report (ARCOPOLplus, 2012):

Task 3.3.1.1: Selection of HNS for modelling applications
Task 3.3.1.2: Technical Report on HNS model implementation

This report was published in December 2012. The text below describes how the ARCOPOL list was established. The text is taken from the above report.

A methodology was developed by Pembrokeshire County Council and the Health Protection Agency to prioritize HNS based upon potential public health risks. The work, undertaken as part of the project, aimed to provide information for use by operators, regulators and responders to incidents, enhancing the efficiency of the response and therefore reducing the overall risks to public health.

A methodology has been developed to prioritize potential acute public health risks associated with incidents involving maritime transport of hazardous and noxious substances (HNS). The methodology does not provide a process for assessing risks for specific incidents but instead aims to provide strategic risk information for public health planning and preparedness.

The prioritisation list of HNS has 350 chemicals and results were compiled in a usable database tool. The prioritisation methodology takes into consideration the tonnage (traffic rank), behaviour based on physico-chemical properties, and toxicity to public health. The table below lists all the chemicals that have a final risk score above 100, based on the defined risk scale.

Table 2-3 Arcopol Top 20 list (Arcopol, 2011)

CHEMICAL NAME	Toxicity	Behaviour score	Tonnage Score	Risk (Product)
CHLORINE GAS	7	10	4	280
ETHYLENE OXIDE	7	10	4	280
METHYL AMINE SOLN	7	9	3	189
AMMONIA	5	9	4	180
2-(2-AMINOETHOXY) ETHANOL	7	8	3	168
VINYL CHLORIDE	4	10	4	160
2-AMINO-2-METHYL-1-PROPANOL	7	7	3	147
3-METHYL PYRIDINE	6	7	3	126
FORMALDEHYDE	7	9	2	126
DIMETHYLAMINE	6	9	2	108
HYDROFLUORIC ACID	6	9	2	108
METHYLAMINE ACID	4	9	3	108
TRIMETHYLAMINE	6	9	2	108
ALUMINIUM CHLORIDE	7	5	3	105
ZINC BROMIDE	7	5	3	105
ZINC CHLORIDE	7	5	3	105
ANILINE	5	5	4	100
METHANOL	4	5	5	100
CYCLOHEXYLAMINE	7	7	2	98
OLEYLAMINE	7	7	2	98

Note that the risk score in this table runs from 280 to 100. There is therefore a large difference between the dangers presented by the various substances in this list.

2.2 Vessels used for transportation

There is a large variation of vessels carrying dangerous goods. Types of vessels that carry HNS cargo in bulk are:

- Chemical tankers;
- Product tankers;
- LPG tankers.

Chemical tankers are divided into three classes (1 to 3). The classification indicates the amount of measures taken to prevent the escape of cargo, class 1 is the highest class. Chemical tankers are in general not that large, the largest tankers are in the order of 80,000 tonnes DWT with a length of 250 meters. However the majority are much smaller in the order of 15 to 20,000 DWT with a length of 150 meters. These vessels are equipped to carry various types of chemicals. They have separated tanks which are often separated by cofferdams and each tank has its own piping and pump facilities. The average size of the tanks is small. Due to the size and the tank arrangement the probability that a specific tank containing a specific chemical is damaged is smaller than for other tankers.

Product tankers in general carry oil products (petrochemicals) from the refineries to the consumer market. Their size varies between 10,000 and 60,000 DWT. The average length is approximately 160 meters. Their cargo tanks are smaller than the tanks of tankers carrying crude, but larger than those of chemical tankers.

An LPG carrier is a gas carrier designed to carry liquefied petroleum gas in bulk. Their cargo capacity varies between 20,000 and 80,000 m3.

When the vessels that are used to carry HNS in bulk are compared with oil tankers, it can be concluded that HNS transported in bulk is transported in smaller vessels often carrying a number of substances.

2.3 How to make an assessment of HNS risk

To make an assessment of the cargo transported in the BE-AWARE area a data request note was sent out to the ports that together contribute 70 % of the oil and HNS GT respectively for the entire Bonn Agreement area (see also Technical Sub-report 3: Future Traffic Model 2020). For these ports the detailed transport data was requested. To perform a good analysis this detailed data should contain the individual dangerous goods reports for 2011 (e.g. date, IMO/MMSI, substance name, amount, last port, next port). For HNS this data was only received from the ports of Antwerp and Rotterdam at the level of detail required for in-depth analysis. For this reason this report is mainly based on these two data sets.

In order to make a qualitative analysis of the HNS risk two steps were required:

Step 1: An analysis was made of the HNS data for Rotterdam and Antwerp;

Step 2: These HNS data were used to make an assessment of the possible involvement of HNS in a collision.

Step 1: cargo data was received from Antwerp and Rotterdam. The Rotterdam data contained information on cargoes handled in bulk, both oil and HNS. The Antwerp database contains information of both packed goods (containers) and cargo handled in bulk, but here oil was not included. This information has been analyzed in the following way. The top 100 of most transported goods has been determined for bulk (no oil) and packed goods, the latter only for Antwerp. These top 100 are included in Annex 3 for Rotterdam and Annex 4 for Antwerp.

Furthermore for each dataset the division into IMDG classes was made, the amount of GESAMP substances and ARCOPOL substances in the database were determined. The results of this analysis are included in sections 3 and 4.

Step 2: to get insight into the involvement of HNS cargo in accidents the SAMSON accident database has been used. This database contains the number of accidents in the BE-AWARE area for each ship type on a grid of 8 x 8 kilometres. The Rotterdam/Antwerp data have been used to compute the average loading condition for a certain substance for the various ship classes present in the grid cell. In principle the analysis is done per substance (or substance type). In this way we get an insight into the involvement of HNS in collisions. The number of ships and the distribution over the area are realistic; the distribution of the substances is an estimate based on either the data from the port of Antwerp or the port of Rotterdam. Depending on the location of terminals and factories in the Bonn Agreement area other substances might be transported or different quantities of substances.

The result of the calculations is the total amount of HNS involved in a collision and the number of shipments. One vessel can carry multiple shipments of HNS. For a limited number of cases also the actual number of collisions was computed. These results were used to estimate the relation between number of shipments involved and number of collisions.

3. HNS data for Rotterdam

For Rotterdam a full calendar year (2011) of data has been received for substances handled in bulk, both for oil and other substances. The Rotterdam data only gave the name of the substances and that meant that coupling it with other databases was difficult. Sometimes the names were spelt differently and sometimes synonyms were used for the same substance and there were also typing errors. This made the analyses time consuming. For the HNS analyses the Rotterdam database has been used, excluding the oil transported. This means that it includes all HNS but also substances that are harmless.

3.1 General characteristics

All HNS data have been ranked and the top 100 most transported goods are summarized in Annex 3.

In the next table the total amount transported (oil and HNS) and the total amount ‘not oil’ are presented. It should be noted that the ‘not oil’ substances are not necessarily HNS.

Table 3-1 Database Rotterdam: total amount of cargo and HNS

	Total [t]	Shipments [-]	Average amount [t]
Total (HNS and harmless substances)	14277473	5487	2602
Total (complete database)	137277974	15194	9035

The purpose of this study is to give a qualitative assessment of the amount of HNS involved in collisions. To make this assessment figures are used from various databases and results from the SAMSON database. To get an impression of the accuracy of the method the same analyses have been made using the complete database, so including the oil data. These results can be compared with the results from the other BE-AWARE studies. In the main report the focus is on the HNS analyses therefore the results from the analyses of the complete Rotterdam database are included in Annex 2.

3.2 IMDG classification

For the deviation between oil and HNS we use a record in the database that indicates whether the substance is oil or not. The results for the Rotterdam analysis for the HNS substances and harmless substances are shown in the table 3-2:

Table 3-2 IMDG classification for all HNS and harmless substances

Rotterdam, HNS and harmless substances				
IMDG class	Total Rotterdam [t]	Total Rotterdam [%]	Shipments [-]	Shipments [%]
IMDG not linked	2245300	15.73%	1299	23.67%
- (not dangerous)	1580723	11.07%	613	11.17%
1.3G	4	0.00%	1	0.02%
2	37	0.00%	5	0.09%
2.1	673456	4.72%	216	3.94%
2.2	187	0.00%	14	0.26%
2.3	142722	1.00%	8	0.15%
3	6111533	42.81%	2154	39.26%
4.1	14661	0.10%	5	0.09%
4.2	700919	4.91%	56	1.02%
4.3	25	0.00%	1	0.02%
5.1	15673	0.11%	5	0.09%
6.1	274946	1.93%	325	5.92%
8	1118605	7.83%	630	11.48%
9	1385386	9.70%	146	2.66%
x (no IMDG-code found)	13295	0.09%	9	0.16%
Total IMDG code	10438155	73.11%	3566	64.99%
Total	14277473	100.00%	5487	100.00%

Apart from the IMDG classification there are three other classifications:

IMDG not linked: the subdivision in IMDG classes has been automated. However this process was hampered by the use of various synonyms for the same substances and spelling differences in the database. At some point it was not possible to link all the substances to IMDG classes.

- Not dangerous: these substances have no IMDG classification because they are not dangerous.

x(no IMDG-code found): for these substances no IMDG classification was found.

The above table gives a good overview of the HNS transported to Rotterdam. There are three main groups of substances, not dangerous (11%), Class 3 flammable (43%) and 'not linked or not classified' (16%), the definition is included below Table 3-2.

3.3 GESAMP results for Rotterdam

To get insight in the hazard level of the substances handled in Rotterdam, the substances that are on the GESAMP top 100 list have been filtered out of the Rotterdam database. It should be noted that the complete Rotterdam database has been used, not just the top 100 of mostly transported substances as included in Appendix A. A short description of GESAMP is presented in section 2.1.2.

In table 3-3 the amounts of substances from this GESAMP top 100 handled in Rotterdam are shown:

Table 3-3 Substances from the TOP 100 GESAMP list (AMRIE, 2005) transported to Rotterdam

ID	Chemical name	Shipments	Amount	Amount per shipment	A	B	C	D	E
		[-]	[t]	[t]	[-]	[-]	[-]	[-]	[-]
92	1,2,3-Trichlorobenzene	3	1500.0	500.0	+	4	1	I	X
91	Tricresyl phosphate (more than 1% ortho-isomers)	2	970.0	485.0	+	4	1	II	X
80	N,N-Dimethyldodecylamine	11	102.1	9.3	+	4	2	II	X
98	Fenoxaprop-P-ethyl (ISO)	2	7.1	3.5	+	4	1	0	0
	Total	**18**	**2579.2**	**143.3**					

Note that the ID in the table indicates the ranking of the substances in the GESAMP top 100 list.

Concluding: the amounts of very dangerous substances are relatively low and do not contain the most dangerous substances in the Top 100 GESAMP list.

3.4 ARCOPOL results for Rotterdam

Apart from Top 100 GESAMP, substances from the Top 20 ARCOPOL list have also been selected from the Rotterdam database. Also for this selection the complete database has been used. Some more information regarding ARCOPOL is included in section 2.1.3.

The substances from the Top 20 ARCOPOL list transported to Rotterdam are shown in the next table.

Table 3-4 Substances from the Top 20 ARCOPOL list (Arcopol, 2011) transported to Rotterdam

ID	CHEMICAL NAME	Shipments	Amount	Amount per shipment	Toxicity	Tonnage Score	Risk (Product)	Oil
		[-]	[t]	[t]	[-]	[-]	[-]	[-]
4	AMMONIA	8			5	4	180	
6	VINYL CHLORIDE	32	133750	4180	4	4	160	
9	FORMALDEHYDE	76	69231	911	7	2	126	
10	DIMETHYLAMINE	1	900	900	6	2	108	
14	ALUMINIUM CHLORIDE	51	540	11	7	3	105	
17	ANILINE	93	168424	1811	5	4	100	Oil
18	METHANOL	14	189235	13517	4	5	100	
	Total	**275**	**562080**	**2044**				

Conclusion: a considerable amount of substances from the Top 20 ARCOPOL list are handled in the port of Rotterdam. However the average parcel size is relatively small. This is regarded as an indication that these substances are carried by chemical tankers that transport different types of substances.

3.5 Ship classes

Initially the idea was to present the contribution of each BE-AWARE ship class to the transport of oil and HNS cargo. However, as some ship classes contribute only a little to total transport and because the differences between some classes are unclear it was decided to reduce the number of ship classes. The resulting distribution is presented in the next table.

Table 3-5 Ship types used for the transportation of HNS and harmless substances (Rotterdam)

ShipType	HNS + harmless substances	
	[t]	[%]
Bulk / Oil Carrier	2076589	14.54%
Chemical / Oil Products Tanker	9818297	68.77%
Crude Oil Tanker	82021	0.57%
LPG Tanker	789713	5.53%
Oil Products Tanker	1470847	10.30%
Vegetable Oil Tanker	40006	0.28%
Totals	**14277473**	**100%**

The HNS cargo is mainly transported by Chemical tankers and Oil Products Tanker (or combined). This accounts for 78 percent of all the HNS cargo. In the next tables the above results are presented per IMDG class.

Table 3-6 Ship types used for the transportation of IMDG goods (Rotterdam)

HNS and harmless substances	IMDG - class													
ShipType	not rated or unknown	1.3G	2	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	6.1	8	9
Bulk / Oil Carrier	0.9%	0.0%	0.0%	0.0%	0.0%	2.5%	0.6%	0.0%	33.8%	0.0%	0.2%	0.2%	0.3%	61.6%
Chemical / Oil Products Tanker	32.8%			1.6%			50.7%	0.1%			0.1%	2.6%	11.0%	1.0%
Crude Oil Tanker	93.5%						6.5%							
LPG Tanker	19.9%			65.4%		11.6%	1.8%						1.3%	
Oil Products Tanker	22.3%			0.1%			75.3%					0.8%	1.2%	0.3%
Vegetable Oil Tanker	100.0%													

4. HNS data for Antwerp

The analysis of the Antwerp data is much easier as it included the UN numbers for most substances. The database is named: 'Dangerous goods reports 2011' but it includes records that refer to oil cargo. In Annex 4 the top 100 most handled substances in the port of Antwerp are presented, both for bulk cargo and for packed goods.

In section 4.6 a comparison between the data for Rotterdam and Antwerp is made.

4.1 General characteristics

The amount of cargo transported to Antwerp is summarized in the next table. This table is based on the 'Dangerous goods reports 2011', as received from the port of Antwerp.

Table 4-1 Total amount of cargo included in the Antwerp database

	Total [t]	Shipments [-]	Average amount [-]
Total amount of bulk cargo	31683760	12408	2553
Total amount of packed cargo	13198301	167721	79
Total	44882061	180129	249

4.2 IMDG classification

The results for the goods transported in bulk are shown below in table 4-2:

Table 4-2 Goods transported to Antwerp according to the IMDG classification

	All		Containers				Bulk			
IMDG-code	Amount [t]	Total [%]	Amount [t]	Total [%]	Shipments [-]	Shipments [%]	Amount [t]	Total [%]	Shipments [-]	Shipments [%]
Not linked	1943463	4.32%					1943463	6.13%	1356	10.93%
-	4839523	10.77%					4839523	15.27%	511	4.12%
1	0	0.00%	0	0.00%	1	0.00%				
1.1B	30	0.00%	30	0.00%	17	0.01%	0	0.00%	1	0.01%
1.1C	2	0.00%					2	0.00%	1	0.01%
1.1D	76	0.00%	73	0.00%	48	0.03%	2	0.00%	7	0.06%
1.1E	15	0.00%	1	0.00%	6	0.00%	14	0.00%	1	0.01%
1.1F	5	0.00%	0	0.00%	1	0.00%	5	0.00%	2	0.02%
1.2C	19	0.00%	16	0.00%	8	0.00%	3	0.00%	2	0.02%
1.2D	1	0.00%	1	0.00%	3	0.00%				
1.2E	1	0.00%	1	0.00%	3	0.00%				
1.2G	4512	0.01%	12	0.00%	2	0.00%	4500	0.01%	1	0.01%
1.3C	1722	0.00%	1657	0.01%	147	0.09%	64	0.00%	3	0.02%
1.3G	93	0.00%	90	0.00%	21	0.01%	2	0.00%	6	0.05%
1.4B	5	0.00%	5	0.00%	7	0.00%				
1.4C	182	0.00%	182	0.00%	20	0.01%				
1.4D	12	0.00%	12	0.00%	9	0.01%	0	0.00%	1	0.01%
1.4E	0	0.00%	0	0.00%	1	0.00%				
1.4G	7127	0.02%	629	0.00%	136	0.08%	6498	0.02%	17	0.14%
1.4S	3635	0.01%	3623	0.03%	481	0.29%	12	0.00%	19	0.15%
1.5D	1	0.00%	1	0.00%	1	0.00%				
2	103663	0.23%	101847	0.77%	5216	3.11%	1360	0.00%	280	2.26%
2.1	6140767	13.66%	14005	0.11%	1510	0.90%	6101640	19.26%	1458	11.75%
2.2	94354	0.21%	90112	0.68%	7171	4.28%	3976	0.01%	436	3.51%
2.3	736448	1.64%	9739	0.07%	1022	0.61%	726641	2.29%	69	0.56%
3	13714182	30.52%	3439047	26.06%	52896	31.54%	10269685	32.41%	4208	33.91%
4.1	267751	0.60%	193470	1.47%	4837	2.88%	74247	0.23%	41	0.33%
4.2	539749	1.20%	538305	4.08%	2110	1.26%	1364	0.00%	37	0.30%
4.3	90767	0.20%	89343	0.68%	1460	0.87%	944	0.00%	12	0.10%
5.1	3171132	7.06%	2783409	21.09%	7383	4.40%	384889	1.21%	171	1.38%
5.2	22839	0.05%	16753	0.13%	1214	0.72%	5994	0.02%	13	0.10%
6.1	2931981	6.52%	1718455	13.02%	18557	11.06%	1210181	3.82%	699	5.63%
7	10932	0.02%	10932	0.08%	191	0.11%	0	0.00%	1	0.01%
8	5707773	12.70%	1930859	14.63%	44238	26.38%	3768155	11.89%	1988	16.02%
9	4606036	10.25%	2255691	17.09%	19004	11.33%	2340596	7.39%	1067	8.60%
Totals:										
IMDG 1-9	38155811	84.91%	13198301	100.00%	167721	100.00%	24900774	78.59%	10541	84.95%
All	44938797	100.00%	13198301	100.00%	167721	100.00%	31683760	100.00%	12408	100.00%

IMDG not linked: the subdivision in IMDG classes has been automated. However this process was hampered by the use of various synonyms for the same substances and spelling differences in the database. At some point it was not possible to link all the substances to IMDG classes.

- Not dangerous: these substances have no IMDG classification because they are not dangerous.

It should be noted that when comparing the absolute values of Antwerp and Rotterdam the latter handles approximately 3 times more cargo. However when HNS amounts are compared we can conclude that Antwerp handles three to four times more HNS cargo. A further comparison between Rotterdam and Antwerp is included in section 4.6.

The packed good analysis (containers) shows that 5 classes are mainly contributing to the total of dangerous goods handled: Flammable liquids (3), Oxidizing substances and organic peroxides (5), Toxic and infectious substances (6), Corrosive substances (8) and Miscellaneous dangerous substances and articles (9).

4.3 Top 100 GESAMP list (bulk and packed)

Also from the Antwerp database the substances have been selected that are on the Top 100 GESAMP list. Although the focus of GESAMP is on goods transported in bulk this analysis has also been executed for the packed goods. For these analyses the complete list of goods handled in the port of Antwerp was used. Extra effort was put into the cross referencing with GESAMP categorisation so all goods from the GESAMP list are included in the analyses.

The substances of the TOP 100 GESAMP list handled in Antwerp are shown in the next table.

Table 4-3 Goods from the TOP 100 GESAMP list (AMRIE, 2005) transported to Antwerp

ID	SubstanceName_GESAMP	IMDG class [-]	UN_nr [-]	Shipments [-]	Amount [t]	Amount per Shipment [t]	A [-]	B [-]	C [-]	D [-]	E [-]	Bulk/ Packed
21	Cadmium compounds (N.O.S.)			113	3250.3	28.8	+	5	2	II	X	Packed
41	Mercuric chloride		1624	47	1.3	0.0	+	4	4	II	X	Packed
41	Mercuric chloride		1624	1	0.0	0.0	+	4	4	II	X	Bulk
43	Phosphorus (elemental yellow)		1338	21	108.1	5.2	+	4	4	II	X	Packed
55	Mercuric acetate		1629	19	0.0	0.0	+	4	3	II	X	Packed
57	Mercuric nitrate		1625	9	0.0	0.0	+	4	3	II	X	Packed
58	Mercuric oxide		1641	6	0.0	0.0	+	4	3	II	X	Packed
59	Mercuric sulphate		1633	37	0.1	0.0	+	4	3	II	X	Packed
60	Mercuric sulphate		1645	37	0.1	0.0	+	4	3	II	X	Packed
61	Mercuric thiocyanate		1646	9	0.0	0.0	+	4	3	II	X	Packed
70	Copper cyanides		1587	21	18.0	0.9	+	4	3	I	XX	Packed
70	Copper cyanides		1587	1	0.1	0.1	+	4	3	I	XX	Bulk
72	Copper chloride (solution)		2802	31	530.5	17.1	+	4	3	0	XX	Packed
78	Mercurous nitrate		1627	5	0.0	0.0	+	4	2	II	X	Packed
86	1,5,9-Cyclododecatriene		2518	23	1921.0	83.5	+	4	1	II	X	Packed
88	Polychlorinated biphenyls (chlorinated dibenzofurans less than 1 ppm)		2315	26	996.5	38.3	+	4	1	II	X	Packed
88	Polychlorinated biphenyls (chlorinated dibenzofurans less than 1 ppm)		2315	3	84.6	28.2	+	4	1	II	X	Bulk
91	Tricresyl phosphate (more than 1% ortho-isomers)	6.1	2574	2	19.7	9.9	+	4	1	II	X	Packed
92	1,2,3-Trichlorobenzene	6.1	2321	10	0.5	0.1	+	4	1	I	X	Packed
92	1,2,3-Trichlorobenzene	6.1	2321	2	1000.0	500.0	+	4	1	I	X	Bulk
	Total Packed			**416**	**6846.07**	**16.5**						**Packed**
	Total Bulk			**7**	**1084.67**	**155.0**						**Bulk**
	Totals			**423**	**7930.7**	**18.7**						

Note that for some substances no amount (= 0) is indicated. This means that there are no quantities indicated in the database or amounts less than 10 kg.

First of all it should be noted that the GESAMP list has been set up to rank HNS transported in bulk. So, when the Top 100 GESAMP list is used to analyse the most dangerous goods transported as packed goods, dangerous substances identified as marine pollutants under IMDG that are normally transported as packed goods are not fully included in the analysis. However, as most GESAMP substances in the port of Antwerp are handled as packed goods this can be seen as an indicator that the most dangerous substances are probably handled as packed goods, in containers.

For HNS transported in bulk it can be concluded that the amount of substances from GESAMP list handled is relatively low and that most of these substances are transported as packed goods.

4.4 Top 20 ARCOPOL list (bulk and packed)

For the substances carried in bulk and packed the substances from the ARCOPOL top 20 list have been selected. For this analysis the complete database has been used. Extra effort was made to select ARCOPOL substances from the database. The substances from the Top 20 ARCOPOL list handled in Antwerp are shown below.

Table 4-4: Substances from the TOP 20 ARCOPOL (ARCOPOL, 2011) list transported to Antwerp

ID	CHEMICAL NAME	IMDG-code	Total			Bulk			Packed		
			Shipments	Amount	Amount per Shipment	Shipments	Amount	Amount per Shipment	Shipments	Amount	Amount per Shipment
		[-]	[-]	[t]	[t]	[-]	[t]	[t]	[-]	[t]	[t]
1	CHLORINE GAS	2.3	31	654	21.1	1	6	6.3	30	647	21.6
2	ETHYLENE OXIDE	2.1	24	35	1.5	3	16	5.4	21	19	0.9
2	ETHYLENE OXIDE	2.2	2	12	6.0				2	12	6.0
2	ETHYLENE OXIDE	2.3	216	1429	6.6	1	6	5.6	215	1423	6.6
3	METHYL AMINE SOLN	3	36	1094	30.4				36	1094	30.4
4	AMMONIA	2.3	139	723541	5205.3	61	723182	11855.5	78	359	4.6
4	AMMONIA	8	306	580	1.9	4	30	7.6	302	550	1.8
5	2-(2-AMINOETHOXY)	8	56	2187	39.1				56	2187	39.1
6	VINYL CHLORIDE	2.1	1	3050	3050.0						
7	2-AMINO-2-METHYL-1-PROPANOL					1	3050	3050.0			
8	3-METHYL PYRIDINE										
9	FORMALDEHYDE	3	40	5353	133.8	3	5200	1733.4	37	153	4.1
9	FORMALDEHYDE	4.1	222	15264	68.8	2	23	11.4	220	15241	69.3
9	FORMALDEHYDE	8	199	2333	11.7	6	1183	197.2	193	1150	6.0
10	DIMETHYLAMINE	2.1	84	1203	14.3				84	1203	14.3
10	DIMETHYLAMINE	3	161	694373	4312.9	1	1800	1800.0	160	692573	4328.6
11	HYDROFLUORIC ACID	8	241	1631	6.8	2	0	0.1	239	1630	6.8
12	METHYLAMINE ACID	2.1	91	1556	17.1	1	30	30.0	90	1526	17.0
13	TRIMETHYLAMINE	2.1	6	28	4.7				6	28	4.7
13	TRIMETHYLAMINE	3	13	2	0.2				13	2	0.2
14	ALUMINIUM CHLORIDE	8	244	35408	145.1	4	28	6.9	240	35381	147.4
15	ZINC BROMIDE										
16	ZINC CHLORIDE	8	224	3843	17.2	2	22	11.0	222	3821	17.2
17	ANILINE	6.1	146	302854	2074.3	68	300835	4424.1	78	2019	25.9
18	METHANOL	3	748	1077235	1440.2	97	1072471	11056.4	651	4764	7.3
19	CYCLOHEXYLAMINE	8	193	4898	25.4				193	4898	25.4
20	OLEYLAMINE										
	Total		**3423**	**2878562**	**840.9**	**257**	**2107883**	**8201.9**	**3166**	**770679**	**243.4**

Conclusion: also for Antwerp a significant amount of substances from the Top 20 ARCOPOL list are handled. The amounts were much bigger in Antwerp, both the total amount handled and the average amount on board.

When a comparison was made between the ARCOPOL substances carried in bulk and as packed goods it can be concluded that the variety of ARCOPOL substances handled as packed goods was larger. However, with over 10 times more shipments, these are handled in much smaller quantities. Despite these smaller quantities the packed goods contribute 27 per-cent of the total amount of Top 20 ARCOPOL substances handled in Antwerp.

4.5 Ship classes

Also for Antwerp the cargo transported is more widely distributed over the ship classes. As some classes seem rather similar or contribute only a little to the total cargo transported they have been combined.

An overview of the ship classes and the cargo carried is shown in table 4-5.

Table 4-5 Ship classes used for the transport of goods

Ship type	Total		Bulk		Packed	
	[t]	[%]	[t]	[%]	[t]	[%]
Bulk Carrier	288198	0.64%	288198	0.92%		
Chemical / Oil Products Tanker	22380467	49.80%	22380467	71.21%		
Container / Ro-Ro Cargo Ship	13198219	29.37%			13198219	97.68%
Crude Oil Tanker	235877	0.52%	235877	0.75%		
General Cargo Ship	254563	0.57%			254563	1.88%
LPG Tanker	6836525	15.21%	6836525	21.75%		
Oil Products Tanker	1686063	3.75%	1686063	5.36%		
Refrigerated Cargo Ship	2044	0.00%			2044	0.02%
No type indication	56734	0.13%			56734	0.42%
Total	**44938690**	**100.00%**	**31427130**	**100.00%**	**13511560**	**100.00%**

This analysis shows that the majority of the bulk cargo is transported by chemical or oil products tankers. The majority of the packed goods is transported by container vessels (the contribution of RoRo vessels is also small).

When the data for the goods transported in bulk are compared with the Rotterdam data it can be concluded that the content of this database is comparable to the database 'bulk no oil' as prepared from the Rotterdam data.

4.6 Summary of data analyses and conclusions

From Rotterdam and Antwerp databases have been received with data on the dangerous goods handled in 2011. Both databases have been analysed and a summary of this analysis is included in this section. An overview of the totals is included in table 4-6.

Table 4-6 Totals of HNS analysis for Antwerp and Rotterdam

	Antwerp						Rotterdam
	Total		Packed		Bulk		Bulk
	Amount [t]	Contribution to total [%]	Amount [t]	Contribution to total [%]	Amount [t]	Contribution to total [%]	Amount [t]
Total (HNS + harmless substances)	44938797	100.00%	13198301	29.37%	31683760	70.50%	14277473
IMDG 1-9	38155811	100.00%	13198301	34.59%	24900774	65.26%	10438155
Arcopol	2878562	100.00%	770679	26.77%	2107883	73.23%	562080
GESAMP	7931	100.00%	6846.07	86.32%	1085	13.68%	2579

In the next two sections a comparison has been made between Rotterdam and Antwerp for the goods handled in bulk and between the goods handled in bulk and as parcels in the port of Antwerp.

4.6.1 Comparison between Antwerp and Rotterdam for bulk goods

In the next table a comparison is made between the goods handled in bulk in Rotterdam and Antwerp. Both databases contain HNS, but also non dangerous goods are indicated as in the above sections.

Table 4-7 Comparison of HNS transported in bulk to Rotterdam and Antwerp

Goods transported in bulk	Rotterdam				Antwerp				Comparison
	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Rotterdam/ Antwerp
Total (HNS + harmless substances)	14277473	100.00%	5487	2602	31683760	100.00%	12408	2553	45%
Total IMDG 1-9	10438155	73.11%	3566	2927	24900774	78.59%	10541	2362	42%
Total ACROPOL	562080	3.94%	275	2044	2107883	6.65%	257	8202	27%
Total GESAMP	2579	0.02%	18	143	1085	0.00%	7	155	238%

In the last column the data for Rotterdam and Antwerp have been compared. The amount of HNS handled in bulk in Antwerp is approximately a factor two (2.2) larger than in Rotterdam.

In Antwerp the variation in the IMDG classification of the substances was much larger than for Rotterdam, see Table 4-2 for Antwerp and Table 3-2 for Rotterdam. For Antwerp the substances were divided over 26 IMDG classes for Rotterdam only over 14 classes. However, many classes give a relatively small contribution. The next figure shows a comparison between Antwerp and Rotterdam for those IMDG classes that contribute more than 1% to the total.

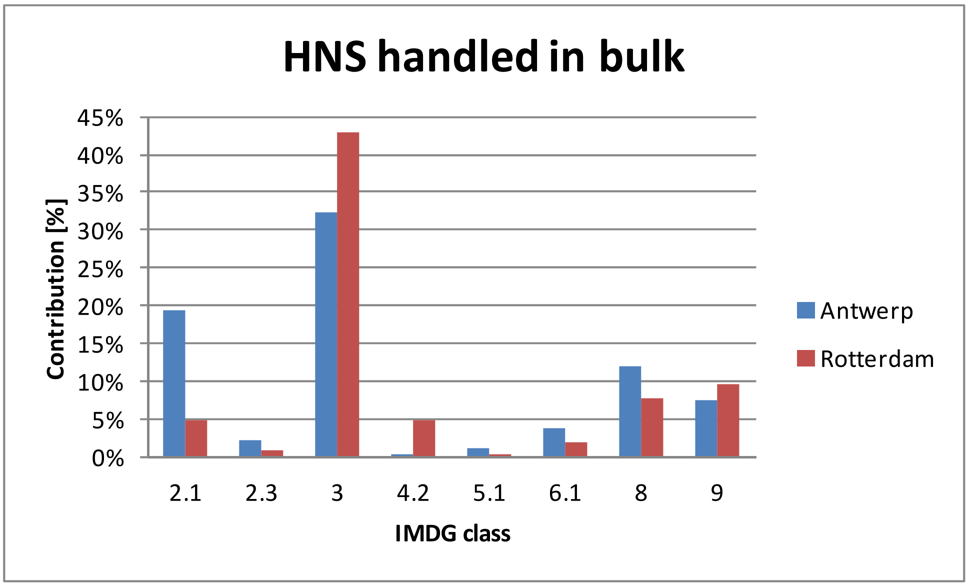


Figure 4-1: IMDG classification of bulk cargo for Rotterdam and Antwerp (contribution larger than 1%)

Comparing the amounts handled from the Top 20 ARCOPOL list one can conclude that Antwerp handles almost 5 times more Top 20 ARCOPOL classified substances in bulk compared to Rotterdam. For GESAMP it is the other way around, Rotterdam handles more. But the amounts are extremely small in both ports. This makes the comparison less valuable.

4.6.2 Comparison bulk and packed goods

This comparison can only be made for Antwerp. In the next table the amount of cargo handled as packed or as bulk is summarised.

Table 4-8 Comparison of HNS transported in bulk and packed to Antwerp

Antwerp	Packed				Bulk				Comparison
	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Packed/Bulk
Total (HNS + harmless substances)	13198301	100.00%	167721	79	31683760	100.00%	12408	2553	42%
IMDG 1-9	13198301	100.00%	167721	79	24900774	78.59%	10541	2362	53%
Arcopol	770679	5.84%	3166	243.4	2107883	6.65%	257	8202	37%
GESAMP	6846	0.05%	416	16.5	1085	0.00%	7	155	631%

From this table it can be concluded that in the port of Antwerp a considerable amount of HNS cargo is handled as packed goods, the amount of packed goods is approximately 50% of the amount of bulk. This is a large amount, certainly when it is realised that the parcel size is much smaller.

Comparing the IMDG classification for packed and bulk it can be concluded that a larger variation of goods is transported as parcel (32 IMDG classes) than in bulk (26 IMDG classes). For both bulk and parcels a number of classes contain very small amounts of cargo, see also Table 4-2. The next figure gives an overview of those IMDG classes that contribute more than 1 per-cent to the total.

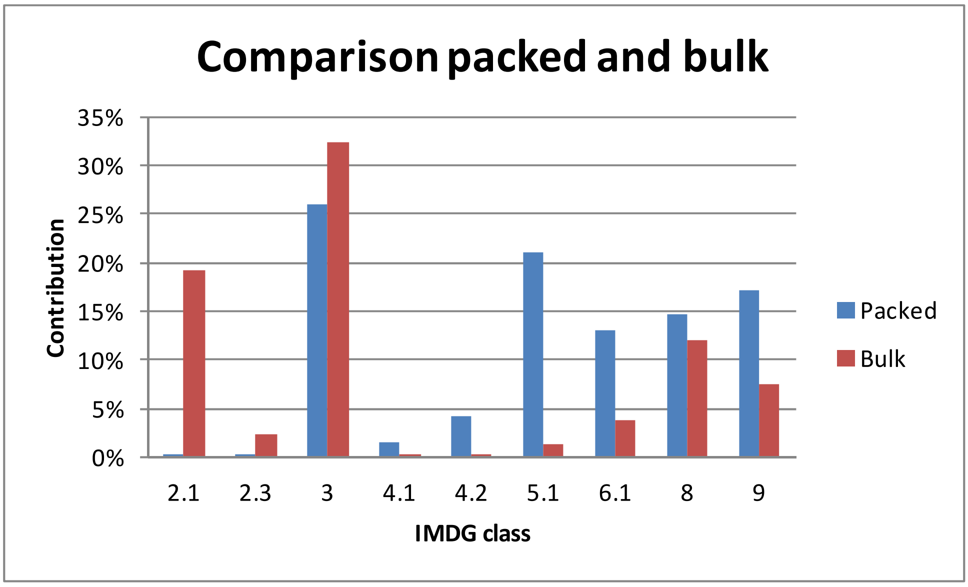


Figure 4-2 Comparison of the IMDG classification of cargo transported packed and as bulk (contribution larger than 1%)

The TOP 20 ARCOPOL substances are handled more often as bulk cargo. But approximately 6% of the HNS handled is from the TOP 20 ARCOPOL list, both for packed and bulk.

The result found for substances from the Top 100 GESAMP list is of special interest. The GESAMP list has been set-up to rank HNS transported in bulk. When the Top 100 GESAMP list is used to analyse the most dangerous goods transported as packed goods, dangerous substances identified as marine pollutants under IMDG that are normally transported as packed goods are not fully included in the analysis. However, as most GESAMP substances in the port of Antwerp are handled as packed goods this can be seen as an indicator that probably the most dangerous substances are handled as packed goods, in containers.

5. Qualitative Risk analysis

5.1 Introduction

In this section an estimate is made of the probability that HNS is involved in collisions. To make this estimate the HNS data was added to the SAMSON result database for the BE-AWARE area. The cargo data was relatively distributed over all vessels. This has been done twice, once using the Rotterdam database for HNS handled in bulk and once using the Antwerp database for HNS handled in bulk and packed. In this way an impression of the amount of HNS cargo involved in collisions was gained. It should be realised that often more HNS is transported in the same vessel. For this reason we also have computed the collision probability of all vessels carrying HNS in bulk separately.

It is recognised that this is not a very accurate method. To get insight in the validity the following analyses have been made:

- Involvement of IMDG classified substances in collisions;
- Involvement of TOP 20 ARCOPOL classified substances involved in collisions;
- Involvement of chemical class I and II tankers involved in collision.

Furthermore, the analyses are repeated for the complete Rotterdam database. This database contains all bulk cargo, so also oil. This result is therefore more comparable to the other results obtained in the BE-AWARE project. It gives an indication of whether the magnitudes of the results were reliable.

5.2 HNS transported in bulk: estimation of the risk collisions

The analyses of HNS transported in bulk are mainly based on the data from Rotterdam. In the last paragraph of this section a comparison will be made with Antwerp.

5.2.1 IMDG classification

An overview of the result for the BE-AWARE area on the basis of the Rotterdam data is shown in table 5-1. This table shows per IMDG class the amount of cargo involved in a collision per year and the number of shipments involved of this specific IMDG class. The main purpose of this task is to get insight into the qualitative risk of the transport of HNS. It is not really necessary to produce extremely accurate values but to gain an understanding of the most critical areas in the Bonn Agreement area and classification of the substances involved. The BE-AWARE project is about oil and includes a detailed analysis of the number of collisions and the amount of oil spilt. In this analysis also the database including oil has been used, results of this analysis are used to benchmark the study.

Table 5-1 Amount of substances involved in collisions (according to IMDG classification)

Amount involved in collisions (HNS and harmless substances)				
Class [-]	**Amount [t]**	**Amount [%]**	**Shipments Per year**	**Shipments [%]**
Not linked	257	8.81%	0.053	1.32%
0	443	15.21%	0.562	14.04%
1.3G	0	0.00%	0.000	0.00%
2	8	0.29%	0.489	12.22%
2.1	273	9.35%	0.047	1.17%
2.2	3	0.09%	0.176	4.39%
2.3	173	5.95%	0.020	0.51%
3	811	27.82%	1.018	25.44%
4.1	2	0.08%	0.017	0.42%
4.2	225	7.70%	0.009	0.22%
4.3	1	0.02%	0.009	0.21%
5.1	6	0.22%	0.090	2.26%
6.1	36	1.24%	0.268	6.70%
8	162	5.56%	0.692	17.29%
9	512	17.57%	0.551	13.77%
x	3	0.09%	0.002	0.04%
Total	**2916**		**4.00**	
Total IMDG	**2213**		**3.39**	

Note: based on Rotterdam data

Apart from the IMDG classification there are three other classifications:

IMDG not linked: the subdivision in IMDG classes has been automated. However this process was hampered by the use of various synonyms for the same substances and spelling differences in the database. At some point it was not possible to link all the substances to IMDG classes.

0 (Not dangerous): these substances have no IMDG classification because they are not dangerous.

x(no IMDG-code found): for these substances no IMDG classification was found.

This table shows that per year 2915 tonnes or in total 4 shipments are involved in an accident. These amounts include harmless substances (class 0) or cargo without classification; it is assumed that these substances are harmless and should be excluded from HNS result. Therefore a second total 'Total IMDG' is presented.

A separate calculation was undertaken to discover number of vessels carrying HNS that were involved in a collision, as a vessel can carry more than one "shipment". This has only been done for the category 'no oil', which includes harmless substances (class 0) or cargo without classification. For this category it was found that there were 1.45 collisions per year involving vessels carrying HNS. In order to calculate the number of collisions that involve vessels carrying IMDG only the ratio between the total number of shipments involved in collisions and the number shipments involved in collisions carrying IMDG only was be used to adjust the figure. This gives a result of 1.23 accidents per year that involve vessels carrying IMDG.

From the IMDG classification in Table 5-1 insight can be obtained into the contribution of the various substances to the total amount of cargo involved in collisions. IMDG classes that give large contributions are 2.1 (gas), 3 (flammable liquids), 4.2 (flammable solids), 8 (Corrosive) and 9 (Miscellaneous).

5.2.2 Top 20 ARCOPOL classification

A similar analysis has been done for the vessels carrying substances included in the Top 20 ARCOPOL classification. The result of this analysis is shown in table 5-2.

Table 5-2 Amount of substances involved in collisions (according to Arcopol classification)

ID	Chemical name	Amount [t]	Amount [%]	Shipments per year	Shipments [%]
4	AMMONIA		0.00%	0.02	12.27%
6	VINYL CHLORIDE	35.33	39.55%	0.01	5.87%
9	FORMALDEHYDE	6.69	7.49%	0.01	8.08%
10	DIMETHYLAMINE	0.22	0.25%	0.00	0.17%
14	ALUMINIUM CHLORIDE	0.25	0.28%	0.01	6.47%
17	ANILINE	18.76	21.00%	0.02	14.52%
18	METHANOL	28.08	31.43%	0.08	52.62%
	Total	**89.34**		**0.14**	

To estimate the number of accidents with ARCOPOL substances involved the same relationship between the number of vessels involved in collisions and the ratio of shipments is used as before, see also section 5.2.1. When the same relationship is applied the number of collisions that includes vessels that carry Top 20 ARCOPOL substances is approximately 0.052 per year. However, as we are dealing with small numbers it is a bit doubtful whether this is an accurate figure.

5.2.3 Chemical tankers class I and II

Chemical tankers are dedicated to carrying dangerous goods with class I the highest classification. As these vessels potentially carry the most dangerous goods the probability that they are involved in a collision is also computed. Computations have been made for class I and II. The result (as a function of IMDG classification) is shown below.

Table 5-3 Chemical tankers class I and II involved in collisions

Chemical tankers class I and II				
Class [-]	**Amount [t]**	**Amount [%]**	**Shipments per year**	**Shipments [-]**
-	853.03	21.65%	0.10	13.10%
0	393.86	10.00%	0.34	43.98%
2.1	16.08	0.41%	0.01	1.02%
3	2457.33	62.37%	0.25	31.87%
4.1	0.56	0.01%	0.00	0.01%
5.1	2.87	0.07%	0.00	0.05%
6.1	73.62	1.87%	0.03	4.25%
8	125.22	3.18%	0.04	4.72%
9	12.37	0.31%	0.01	0.66%
x	4.89	0.12%	0.00	0.33%
Total	**3939.84**		**0.78**	
Total IMDG	**2688.05**		**0.33**	

In comparison to the other results the amount of cargo involved in a collision is relatively large.

5.2.4 Results for Antwerp, bulk cargo

A similar analysis as for the Rotterdam bulk data has been executed for the Antwerp data. As we re-distribute the cargo over the ships sailing in the BE-AWARE area it is expected that the differences between the two results should be comparable. Of course substances that are included in the original database of Rotterdam will not be found in the overall analyses.

The result of this analysis is using the data for Antwerp is shown below.

Table 5-4 Amount of substances involved in collisions (IMDG classification)

IMDG class	Amount [t]	Amount [%]	Shipments [-]	Shipments [%]
-	453.75	22.76%	0.026	7.14%
0	126.40	6.34%	0.051	14.06%
1.3C	0.00	0.00%	0.000	0.04%
1.3G	0.00	0.00%	0.001	0.15%
1.4G	0.00	0.00%	0.000	0.13%
1.4S	0.00	0.00%	0.001	0.18%
2	0.15	0.01%	0.026	7.21%
2.1	243.92	12.23%	0.063	17.23%
2.2	0.18	0.01%	0.015	4.23%
2.3	20.08	1.01%	0.002	0.68%
3	688.45	34.53%	0.185	50.94%
4.1	15.50	0.78%	0.005	1.33%
4.2	0.36	0.02%	0.010	2.87%
4.3	0.02	0.00%	0.001	0.23%
5.1	10.22	0.51%	0.008	2.33%
5.2	0.01	0.00%	0.001	0.27%
6.1	113.12	5.67%	0.053	14.61%
7	0.00	0.00%	0.000	0.09%
8	217.27	10.90%	0.088	24.19%
9	104.61	5.25%	0.061	16.82%
Total	1994.04		0.599	
Total IMDG	1413.89		0.522	

The total amount of cargo involved in collisions per year is comparable to the result for Rotterdam (no oil). For Rotterdam we find 2900 tonnes per year involved in collisions, the distribution over the various substances is somewhat different. However the total number of collisions is only estimated at 0.36 per year, so once every 3 years.

As the same SAMSON result database was used for both analyses, but with a different distribution of the cargo, a more equal result was expected. Actually the amount of HNS cargo handled in Antwerp was larger than in Rotterdam, see also section 4.6. However, the interest of this study was not the absolute figures but a qualification of the risk. To get an impression of the differences per IMDG class for Antwerp and Rotterdam the contribution of each class to the total result is shown in the next figure.

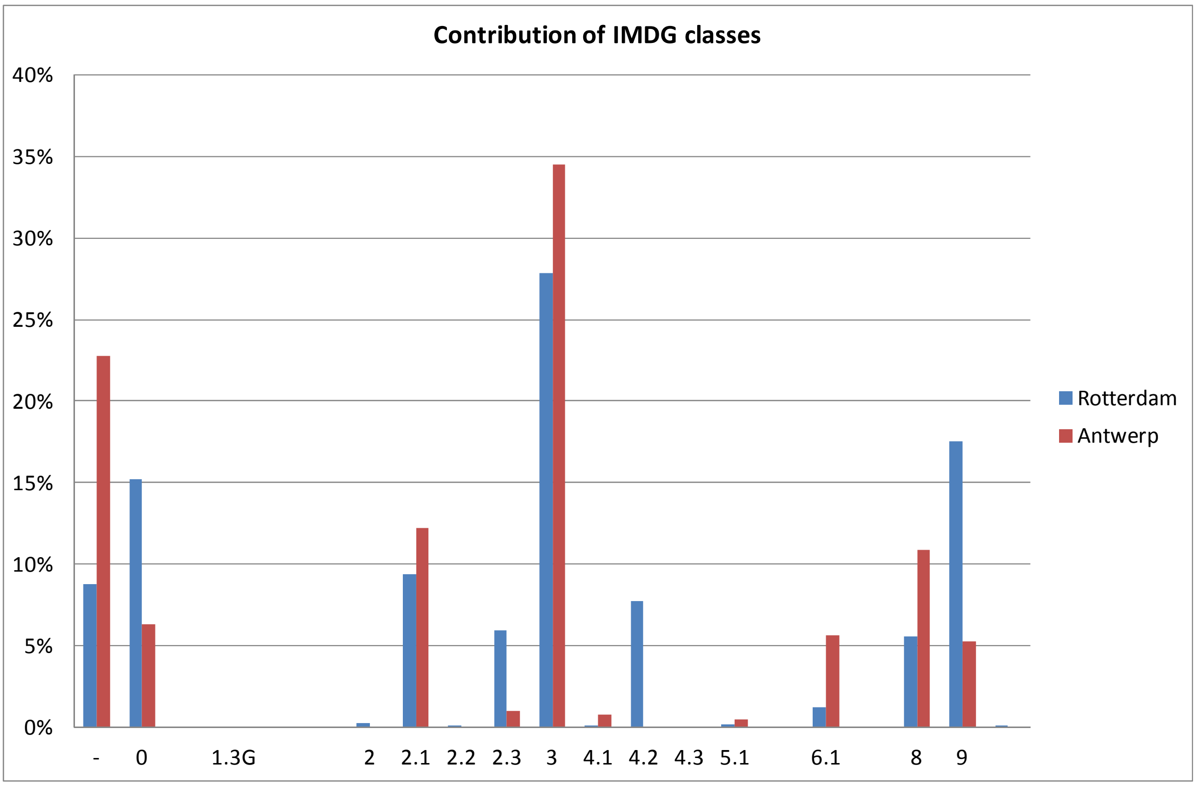


Figure 5-1 Comparison of the contribution of the IMDG classes to the total amount involved in collisions for Rotterdam and Antwerp

From this figure it can be concluded that most IMDG classes are included in both databases. But it also shows that some classes (e.g. 4.1) are only in the Antwerp analysis and other classes (e.g. 4.2) only in Rotterdam. This is related to the specific substances that are handled in the port.

5.2.5 Geographical distribution of the risk of HNS transported in bulk

To get an insight into the distribution of the risk of HNS transported in bulk a number of figures have been prepared. These figures present the average amount of HNS cargo which is per year involved in a collision. The results are plotted on a grid of 8x8 km. A number of subsets have been made in order to get an insight into sensitivity in the result. In the next picture the result is shown for HNS carried in bulk, IMDG code 1-9.

It should be noted that for this analysis a SAMSON result database has been used that includes all traffic in BE-AWARE area. It is assumed that the loading profile of the various vessels corresponds to the loading profile of vessels of ships going to Rotterdam/Antwerp. In absolute terms this result is probably not extremely reliable, but relatively to identify possible risk areas in the BE-AWARE area it gives a good impression. All results for bulk cargo presented here are based on the Rotterdam cargo.

Figure 5-2 IMDG class 1-9 substances involved in collisions (Table 5-3)

The figures included here are repeated in Annex 1 on a larger scale.

It should be noted that, although based on data from Rotterdam, risk concentration are found at the ports of Hull, Mongstad, Oslo, Amsterdam, Western Scheldt and Southampton.

A similar picture is prepared for Arcopol top 20 substances. This result is shown in figure 5-3.

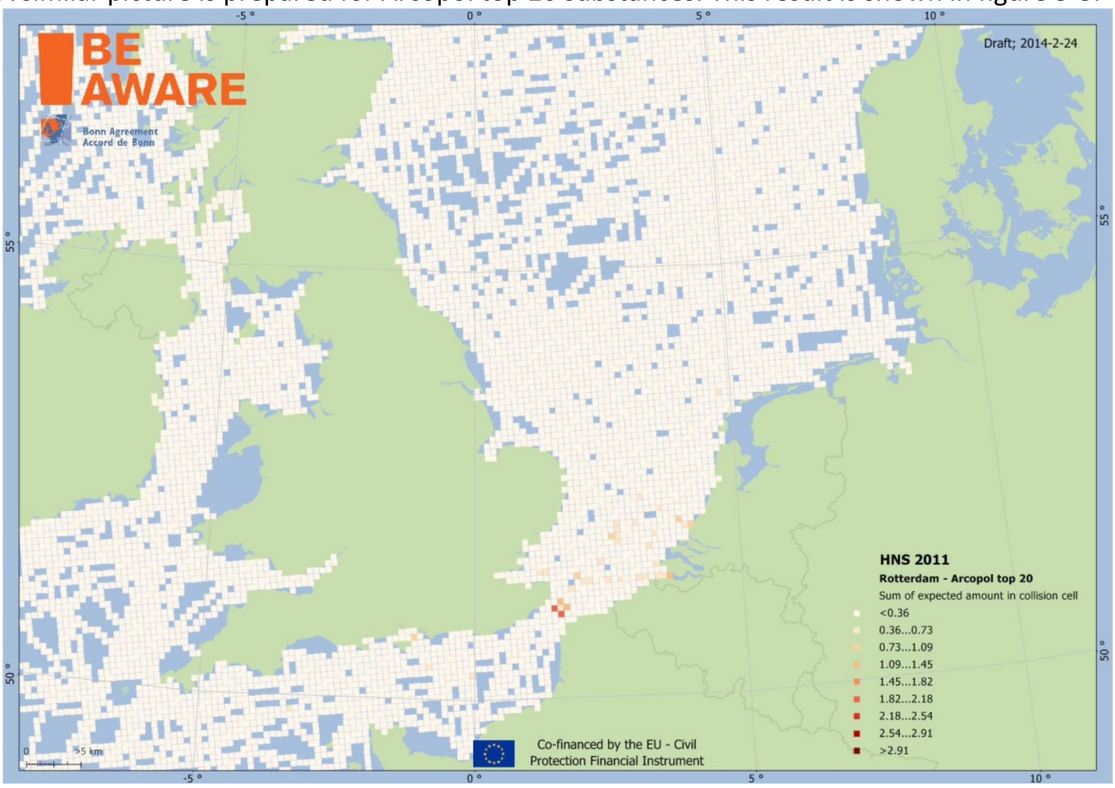


Figure 5-3 Arcopol top 20 substances involved in collisions (Table 5-2)

For these substances we only find a contribution in the North Sea and southern North Sea, but also in ports such as Southampton, Rotterdam, Western Scheldt and the approach to London. It should be noted that in all figures we have used the same legend.

The ports of Rotterdam and Antwerp are among the biggest ports in Europe and in the world. It is clear that a large share of the transported HNS in the North Sea would at one point be sailing in and out of one of those ports. However there are local trade patterns of HNS that are not captured by the analysis in this report because ships that carry HNS sail between local ports only, or because ships sails from a sea area outside the North Sea and directly to their destination i.e. without calling Rotterdam or Antwerp. As a consequence some local risk areas will not have been identified on the above risk maps. HNS substances used locally for specialized industries could be a considerable risk locally, but their quantity would be small compared to the quantities handled in the two ports used for reference in this report. HNS substances transported in and out of oil rigs can be an example of substances transported locally.

Conclusion: when we take a wide range of HNS, the critical areas on the North Sea more or less coincide with the busy shipping routes. When we take a very specific type of substance the risk focuses on the southern North Sea. The latter is an effect of the busy traffic in the area and the fact that relatively large quantities of HNS pass this area.

5.2.6 Summary, bulk cargo

In the table below an overview is given of the various results. It should be realised that the overall collision probability for the BE-AWARE area is approximately 10 collisions per year.

Table 5-5: Summary of the results for Bulk

HNS transported in bulk			
Rotterdam	Amount [t]	Shipments [-]	Collision [-]
HNS and harmless substances	2916	4.00	1.45
HNS (IMDG classes 1-9)	2213	3.39	*1.23*
Chemical tankers I and II	3940	0.78	*0.28*
Chemical tankers I and II, (IMDG classes 1-9)	2688	0.33	*0.12*
TOP 20 ARCOPOL	89	0.14	*0.05*
Antwerp			
HNS and harmless substances	1994	0.60	0.36
HNS (IMDG classes 1-9)	1414	0.52	*0.32*

From the table the following can be concluded (on basis of the data from Rotterdam):

- From the 10 collisions that occur every year in the Bonn Agreement area one collision will include at least one vessel that carries substances classified as IMDG 1-9. Approximately 2200 tonnes of HNS will be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) will include a chemical tanker of class I or II. Per year approximately 3000 tonnes of HNS will be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) will include a vessel that carries substances from the Top 20 ARCOPOL list. Per year approximately 90 tonnes Arcopol HNS will be involved.

When we compare these results with a similar analysis using the data from Antwerp then the average amount of cargo involved in a collision is comparable, but the number of shipments in one collision and the absolute number of collisions is lower.

For the spatial distribution of risk on accidents with HNS involved two results are presented. One result shows the distribution of accidents with vessels carrying IMDG class 1-9 substances. This result is shown in Figure 5-1. The high risk areas more or less follow the shipping routes. The other result shows the distribution of accidents with vessels carrying TOP 20 ARCOPOL substances. This risk is mainly focussed in the Southern North Sea.

5.3 HNS transported in packed form: estimation of the risk of collisions

5.3.1 IMDG classification

A similar analysis has been made for HNS cargo that was transported as packed goods. These substances were mainly transported by containers.

Table 5-6 Amount of packed goods involved in collisions (IMDG classification)

IMDG class	Amount [t]	Amount [%]	Shipments [-]	Shipments [%]
1	0.000	0.00%	0.000	0.00%
1.1B	0.003	0.00%	0.002	0.05%
1.1D	0.008	0.00%	0.003	0.08%
1.1E	0.000	0.00%	0.001	0.03%
1.1F	0.000	0.00%	0.000	0.00%
1.2C	0.004	0.00%	0.002	0.04%
1.2D	0.000	0.00%	0.001	0.02%
1.2E	0.000	0.00%	0.000	0.01%
1.2G	0.001	0.00%	0.000	0.01%
1.3C	0.188	0.02%	0.014	0.33%
1.3G	0.013	0.00%	0.003	0.07%
1.4B	0.000	0.00%	0.001	0.02%
1.4C	0.026	0.00%	0.003	0.08%
1.4D	0.001	0.00%	0.001	0.03%
1.4E	0.000	0.00%	0.000	0.00%
1.4G	0.091	0.01%	0.015	0.36%
1.4S	0.340	0.04%	0.041	0.98%
2	8.785	1.04%	0.416	10.01%
2.1	1.068	0.13%	0.091	2.20%
2.2	8.207	0.97%	0.295	7.10%
2.3	0.632	0.07%	0.055	1.32%
3	168.919	20.02%	0.643	15.48%
4.1	10.582	1.25%	0.247	5.95%
4.2	60.078	7.12%	0.131	3.16%
4.3	6.972	0.83%	0.094	2.27%
5.1	117.017	13.87%	0.330	7.95%
5.2	1.188	0.14%	0.073	1.75%
6.1	142.282	16.86%	0.436	10.50%
7	1.204	0.14%	0.019	0.47%
8	149.888	17.77%	0.614	14.80%
9	166.163	19.70%	0.620	14.93%

Total	843.660		4.150	

It is assumed that these packed (HNS) goods will be involved in 0.8 collisions per year. So this is slightly less than the number of collisions that will include bulk cargo. (Note: average pay-load in a container is 20 tonnes, so 840 tonnes corresponds to 42 containers per year)

5.3.2 Geographical distribution of the risk of HNS transported as packed goods

Also for the substances transported as packed goods the geographical distribution has been determined. The results for packed goods are shown in the next figure. This figure is based on the cargo data from Antwerp.

Figure 5-4 Packed goods containing IMDG 1-9 substances involved in collisions (Table 5-7)

For packed goods, based on data from Antwerp, contributions are found at Rotterdam, Oslo, Southampton, London and Felixstowe.

A separate analysis has been done for IMDG class 6.1 carried as packed goods. This class contains toxic substances. Figure 5-5 shows the geographical distribution of collisions involving these substances.

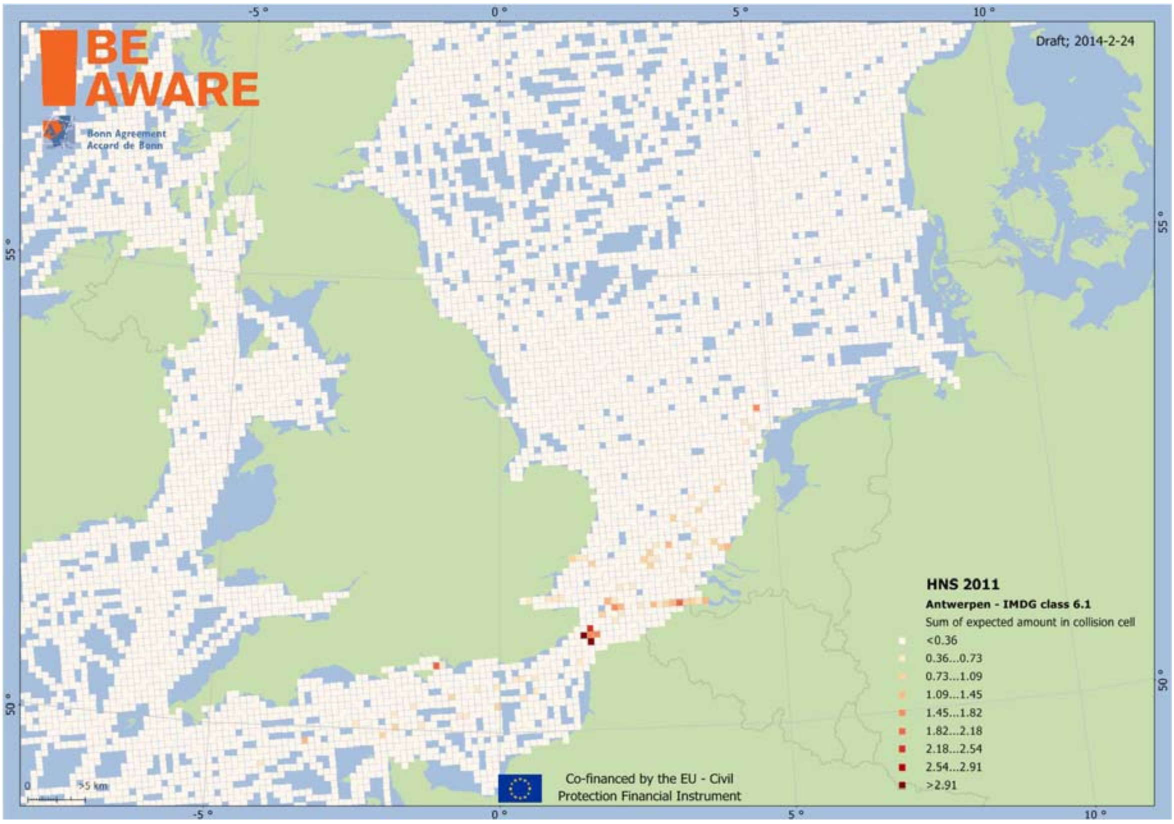


Figure 5-5 Packed goods containing IMDG 6.1 substances involved in collisions (Table 5-6)

Higher risk concentrations are found, amongst others, in the ports of Rotterdam, Southampton and London.

6. Future work on HNS analysis

The analysis of risks related to the transport of HNS showed a number of difficulties that should be accounted for in future projects. The major difficulties are:

1. There are many substances transported by ships, due to this the databases containing all this information are extremely large. Furthermore the databases to monitor HNS transport are not uniform and not always very accurate. Accuracy can be improved by using standard names for substances and always including the UN number in the records.
2. There are different systems to classify the risk of HNS in the marine environment. The IMDG code makes a classification on the basis of the most pre-dominant hazards. The GESAMP list is focussed on the most dangerous substances carried in bulk and the ARCOPOL list focuses on the impact of substances on human health.
3. To apply the existing classifications on all goods transported in the Bonn Agreement area requires much more information of all goods transported and requires much more time. For the HNS transported in bulk a variety of vessels is used, ranging from ordinary tankers to sophisticated class 1 chemical tankers. For these ship types the subdivision into tanks and cofferdams is totally different. Therefore the consequences of an accident, e.g. the probability of a spillage and the amount of spillage, are also very different. These differences have to be taken into account in the analysis of HNS.
4. Much HNS cargo is transported as packed goods, often in containers. Depending on the content, containers containing HNS are located in different places on the vessel. Depending on the location on board of the vessel and the type of accident the status and location of the container after the accident should be determined and the probability of HNS spillage.
5. To determine the probability of HNS spillage the situation after incidents also has to be evaluated. After an accident ships may sink or containers might go overboard. The consequences of a ship or a container on the sea bottom carrying HNS cargo need to be considered in the analysis.
6. Risk from HNS can be said to be a discipline that deserves the main focus. In the BE-AWARE project the main focus has been on oil transport and associated risk/probability. Equally a project that focuses entirely on HNS is advised to be conducted in the near future.

7. Conclusions

For the analysis of the transport of HNS in the Bonn Agreement area only detailed data have been received from the ports of Rotterdam and Antwerp. This study is based on the data from these two ports, and this limits the validity of the conclusions for the complete Bonn Agreement area. The study executed can be divided in three parts:

- Analyses of the HNS handled in Rotterdam and Antwerp;
- Approximation of the probability that HNS is involved in collisions;
- The geographical distribution of HNS involved in collisions.

7.1 Analyses of the HNS handled in Rotterdam and Antwerp

The database received from Rotterdam only contains data of substances handled in bulk. The database received from Antwerp includes both packed and bulk goods. Within this study we can make a comparison between Rotterdam and Antwerp of the data handled in bulk, and a comparison of the substances handled in bulk and packed within the port of Antwerp.

7.1.1 Comparison for bulk goods

In table 7-1 a comparison is made between the goods handled in bulk in Rotterdam and Antwerp. Both databases contain HNS, but also not dangerous goods. When the percentage of the total amount that is classified as IMDG 1-9 is compared for the two ports the percentage for Rotterdam (73%) is slightly smaller than for Antwerp (78%).

Table 7-1 Comparison of HNS transported in bulk to Rotterdam and Antwerp

Goods transported in bulk	Rotterdam				Antwerp				Comparison
	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Rotterdam/ Antwerp
Total (HNS + harmless substances)	14277473	100.00%	5487	2602	31683760	100.00%	12408	2553	45%
Total IMDG 1-9	10438155	73.11%	3566	2927	24900774	78.59%	10541	2362	42%
Total ACROPOL	562080	3.94%	275	2044	2107883	6.65%	257	8202	27%
Total GESAMP	2579	0.02%	18	143	1085	0.00%	7	155	238%

In the last column the data for Rotterdam and Antwerp are compared. The amount of HNS handled in bulk in Antwerp was approximately a factor two (2.2) larger than in Rotterdam.

In Antwerp the variation in the IMDG classification of the substances is much larger than for Rotterdam, see Table 4-2 for Antwerp and Table 3-2 for Rotterdam. For Antwerp the substances were divided over 26 IMDG classes for Rotterdam only over 14 classes. However, many classes give a relatively small contribution. The figure 7-1 shows a comparison between Antwerp and Rotterdam for those IMDG classes that contribute more than 1% to the total.

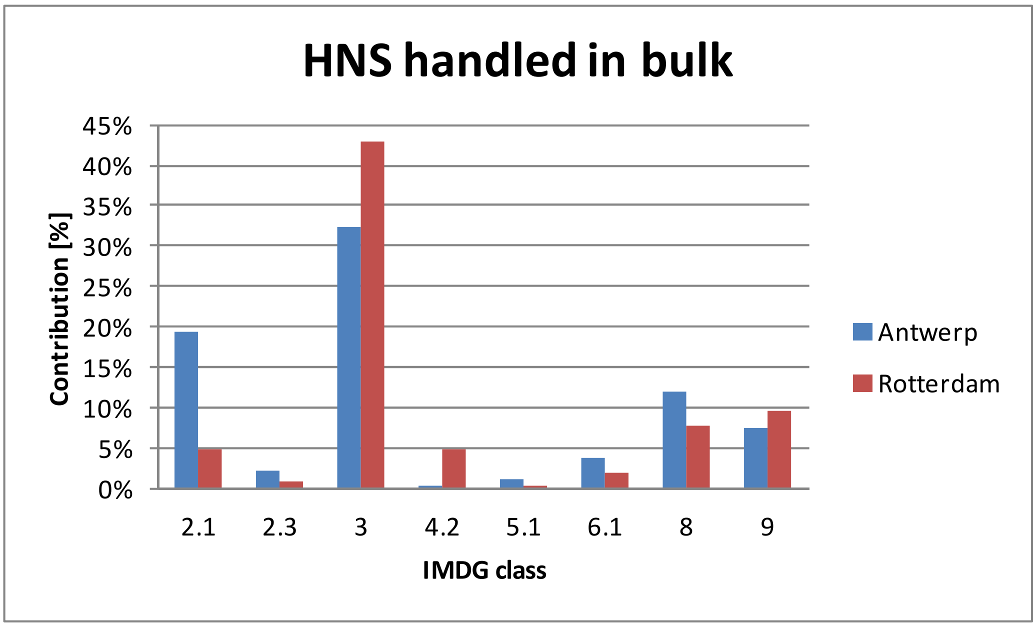


Figure 7-1 IMDG classification of bulk cargo for Rotterdam and Antwerp (contribution larger than 1%)

Comparing the amounts handled from the Top 20 ARCOPOL list one can conclude that Antwerp handles almost 5 times more Top 20 ARCOPOL classified substances in bulk compared to Rotterdam. For GESAMP it is the other way around, Rotterdam handles more. But it should be noted that the amounts are extremely small in both ports, so it is unlikely these comparisons are of key interest.

7.1.2 Comparison bulk and packed goods

This comparison can only be made for Antwerp. In the next table the amount of cargo handled as packed or as bulk is summarized.

Table 7-2 Comparison of HNS transported in bulk and packed to Antwerp

Antwerp	Packed				Bulk				Comparison
	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Packed/Bulk
Total (HNS + harmless substances)	13198301	100.00%	167721	79	31683760	100.00%	12408	2553	42%
IMDG 1-9	13198301	100.00%	167721	79	24900774	78.59%	10541	2362	53%
Arcopol	770679	5.84%	3166	243.4	2107883	6.65%	257	8202	37%
GESAMP	6846	0.05%	416	16.5	1085	0.00%	7	155	631%

From this table it can be concluded that in the port of Antwerp a considerable amount of HNS cargo is handled as packed goods, the amount of packed goods is approximately 50% of the amount of bulk. This is a large amount, certainly when is realised that the parcel sizes were much smaller.

Comparing the IMDG classification for packed and bulk it can be concluded that a larger variation of goods was transported as parcel (32 IMDG classes) than in bulk (26 IMDG classes). For both bulk and parcels a number of classes contain very small amounts of cargo, see also Table 4-2. The figure 7-2 gives an overview of those IMDG classes that contribute more than 1 per-cent to the total.

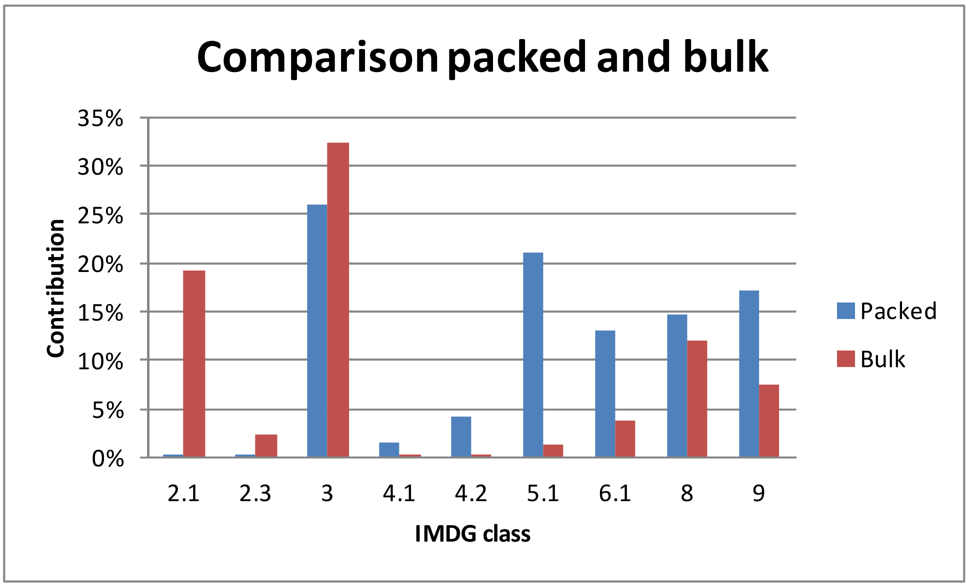


Figure 7-2 Comparison of the IMDG classification of cargo transported packed and as bulk (contribution larger than 1%)

The TOP 20 ARCOPOL substances are handled more often as bulk cargo. But approximately 6% of the HNS handled were from the TOP 20 ARCOPOL list, both for packed and bulk. The result found for substances from the Top 100 GESAMP list is of special interest. The GESAMP list has been set up to rank HNS transported in bulk. So, when the Top 100 GESAMP list was used to analyse the most dangerous goods transported as packed goods, dangerous substances identified as marine pollutants under IMDG that are normally transported as packed goods were not fully included in the analysis. However, as most GESAMP substances in the port of Antwerp are handled as packed goods this can be seen as an indicator that probably the most dangerous substances are handled as packed goods, in containers.

7.2 Approximation of the probability that HNS is involved in collisions

For the Bonn Agreement area an analysis has been made on the probability that HNS is involved in a collision on basis of data from Antwerp and Rotterdam. The result of this analysis is summarised in table 7-3.

Table 7-3 Amount of HNS cargo involved in collisions

HNS transported in bulk			
On basis of Rotterdam data	Amount [t]	Shipments involved in collisions, per year	Vessels involved in collisions, Per year
HNS and harmless substances	2916	4.00	1.45
HNS (IMDG classes 1-9)	2213	3.39	*1.23*
Chemical tankers I and II	3940	0.78	*0.28*
Chemical tankers I and II, (IMDG classes 1-9)	2688	0.33	*0.12*
TOP 20 ARCOPOL	89	0.14	*0.05*
On basis of Antwerp data			
HNS and harmless substances	1994	0.60	0.36
HNS (IMDG classes 1-9)	1414	0.52	*0.32*
HNS transported as packed goods (based on Antwerp data)			
Packed goods in IMDG classes 1-9	844	4.15	0.82

This table presents for various cargo classifications the predicted amount of (HNS) cargo involved in a collision per year, the predicted number of shipments involved in a collision per year and an estimate of the number vessels involved in collisions per year. There can be more than one shipment of a vessel. It should be noted that these figures are very indicative approximations as these are based on the datasets for Rotterdam and Antwerp only. Furthermore these figures only give a first, rough approximation of the number of incidents. They give no indication of the amount of substances spilt.

From the table the following can be concluded (on basis of the data from Rotterdam):

- From the 10 collisions that occur every year in the Bonn Agreement area one collision will include at least one vessel that carries substances classified as IMDG 1-9. Approximately 2200 tonnes of HNS will be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) will include a chemical tanker of class I or II. Per year approximately 3000 tonnes of HNS will be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) will include a vessel that carries substances from the Top 20 ARCOPOL list. Per year approximately 90 tonnes Arcopol HNS will be involved.
- The approximation based on the Antwerp data is somewhat lower than found on basis of the Rotterdam data.

For HNS transported as packed goods the following can be concluded:

- It is estimated that there will be 0.8 collisions per year that involves a vessel with HNS on board;
- The total amount of HNS involved in a collision was 843 tonnes per year, which would include 4 different HNS shipments.

7.3 The geographical distribution of HNS involved in collisions

For both packed goods and bulk goods the geographical distribution of HNS involved in collisions has been determined. For the geographical distribution the results as described in section 7.2 has been used. These results are based on the HNS data received from the ports of Antwerp and Rotterdam only. Below a result is presented for a wide range of substances (IMDG 1-9) and more specific (harmful), ARCOPOL and IMDG 6.1 classes. Note that these figures are also included as large figures in Annex 1.

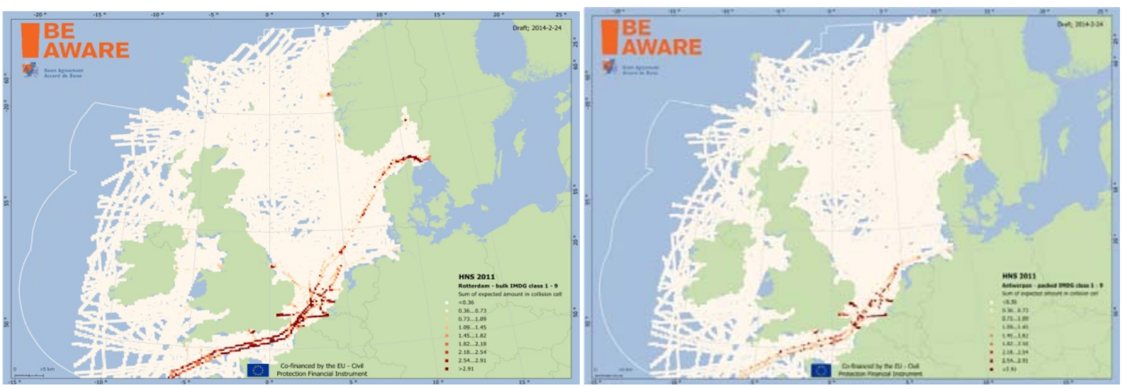


Figure 7-3 IMDG 1-9: left involved in collision as bulk, right as packed goods (containers)

It should be noted that, although based on data from Rotterdam, risk concentration are found at Antwerp, Hull, Mongstad, Oslo and Southampton. For packed goods, based on data from Antwerp, contributions are found at Rotterdam, Oslo, Southampton, London and Felixstowe.

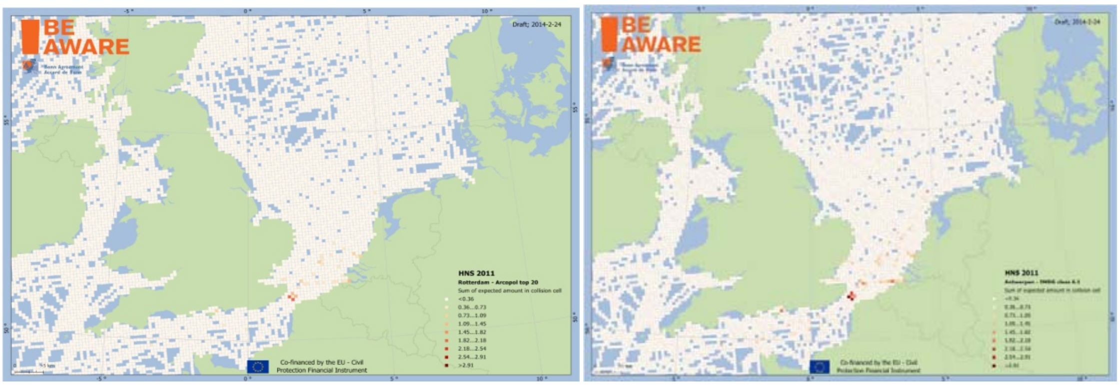


Figure 7-4 Left Top 20 ARCOPOL substances transported in bulk involved in collisions, right IMDG 6.1 transported as packed goods involved in collisions

For goods from the Top 20 ARCOPOL list transported in bulk concentrations of risk are found on the southern North Sea but also in ports like: Southampton, Rotterdam, Western Scheldt and the approach to London.

For packed goods IMDG 6.1 has been further analysed. Higher risk concentrations are found, amongst others, in the ports of Southampton and London.

The ports Rotterdam and Antwerp are among the biggest ports in Europe and in the world. It is clear that a large share of the transported HNS in the North Sea would at one point be sailing in and out of one of those ports. However there are local trade patterns of HNS that are not captured by the analysis in this report because ships that carry HNS sail between local ports only, or because ships sails from a sea area outside the North Sea and directly to their destination i.e. without calling Rotterdam or Antwerp. As a consequence some local risk areas will not have been identified on the above risk maps. HNS substances used locally for specialized industries could be a considerable risk locally, but their quantity would be small compared to the quantities handled in the two ports used for reference in this report. HNS substances transported in and out of oil rigs can be an example of substances transported locally.

8. References

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IMO, 2012 Report of the maritime safety committee on its ninetieth session, MSC 90/28, 31 May 2012. Annex 4, Resolution MSC.328(90)-Adoption of amendments to the International Maritime Dangerous Goods (IMDG) code (Amendment 36-12)

ARCOPOLplus, 2012 Improving maritime safety and Atlantic Regions' coastal pollution response through technology transfer, training and innovation, Activity 3, Task 3.3.1.1: Selection of HNS for modelling applications, Task 3.3.1.2: Technical Report on HNS model implementation

ARCOPOL, 2011 Risk Prioritisation Methodology for Hazardous & Noxious Substances for Public Health, Activity 3, 3.1: HNS Prioritisation Methodology & List

IMO, 2002 The Revised GESAMP Hazard Evaluation Procedure for Chemical Substances Carried by Ships. GESAMP Reports and Studies No. 64

9. Glossary of Definitions and Abbreviations

GESAMP: Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (sponsored by Eight UN Agencies)
IMO: International Maritime Organization (London)
IMDG Code: International Maritime Dangerous Goods Code (packaged dangerous goods, IMO)
ARCOPOL: The Atlantic regions' Coastal Pollution Response project
HNS: Hazardous and Noxious Substances
MARPOL: Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (convention of IMO)
Bulk: Substances transported in large quantities by tankers
Packed: Substances transported in the required quantity and storage form according to the IMDG code;
Parcel: An amount of one specific substance a part of a cargo that contains various other substances.

Annex 1: Large versions of figures 5-2, 5-3, 5-4 and 5-5

Figure 5-2 IMDG class 1-9 substances involved in collisions (Table 5-3)

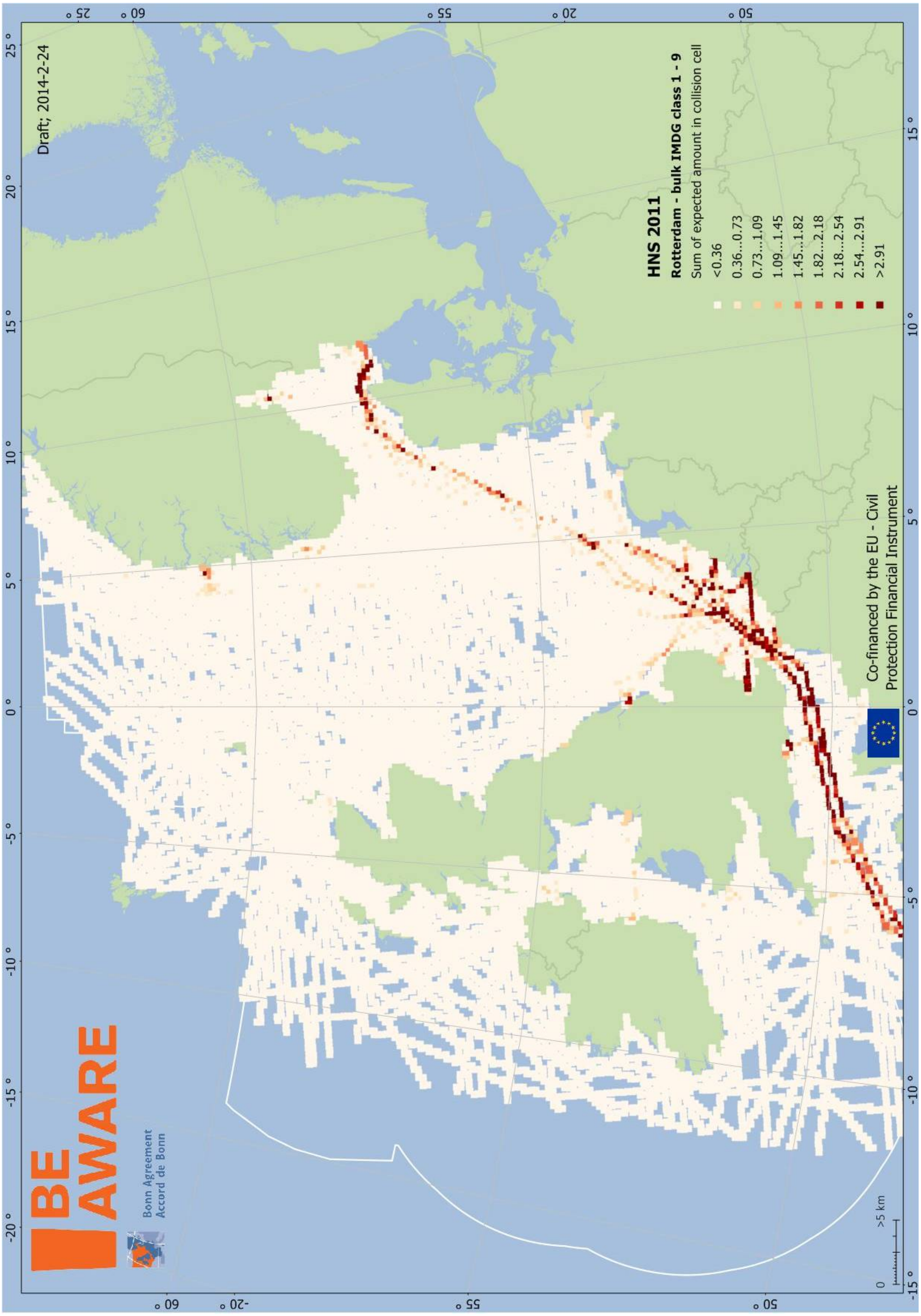


Figure 5-3 Arcopol top 20 substances involved in collisions (Table 5-4)

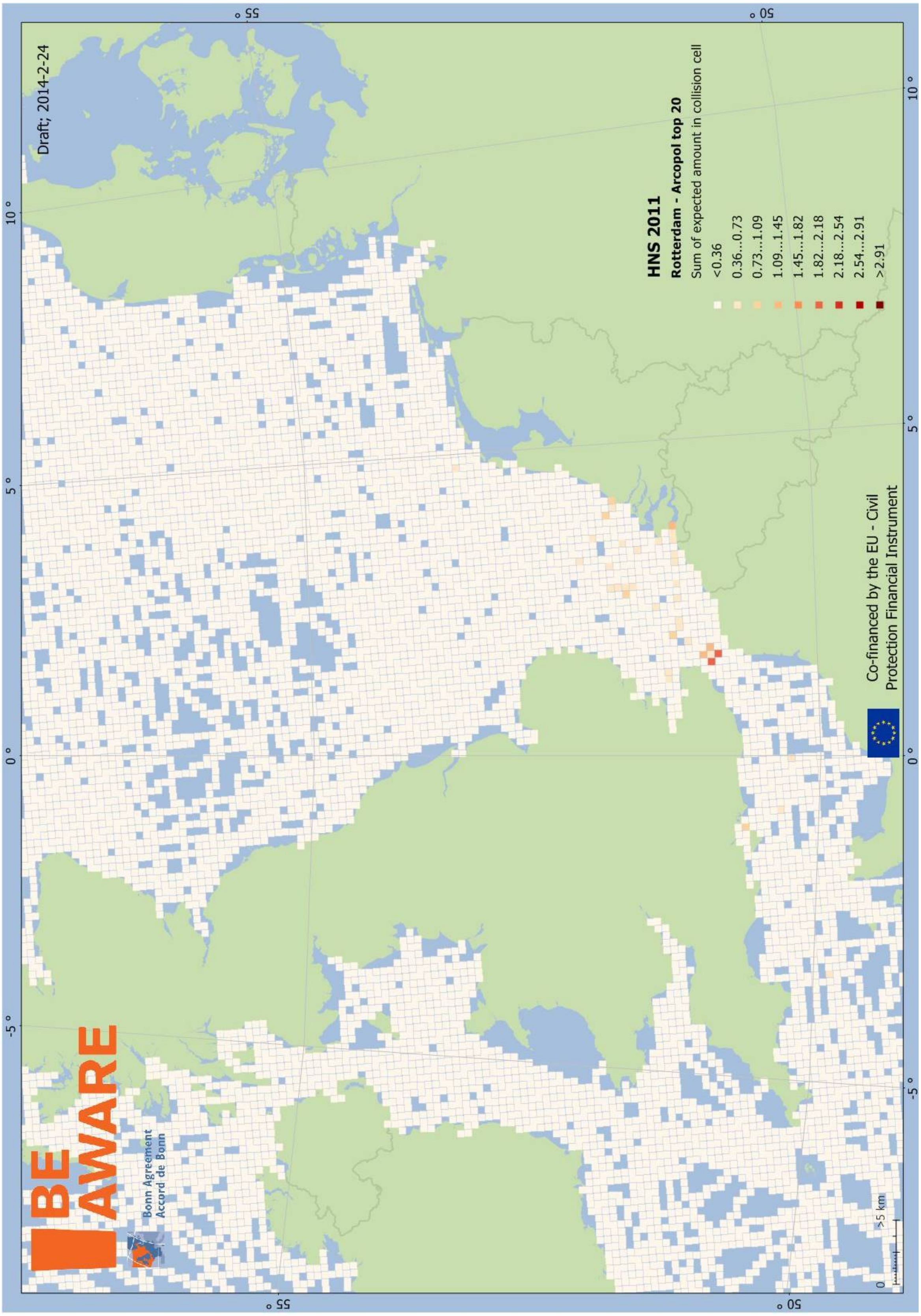


Figure 5-4 Packed goods containing IMDG 1-9 substances involved in collisions (Table 5-7)

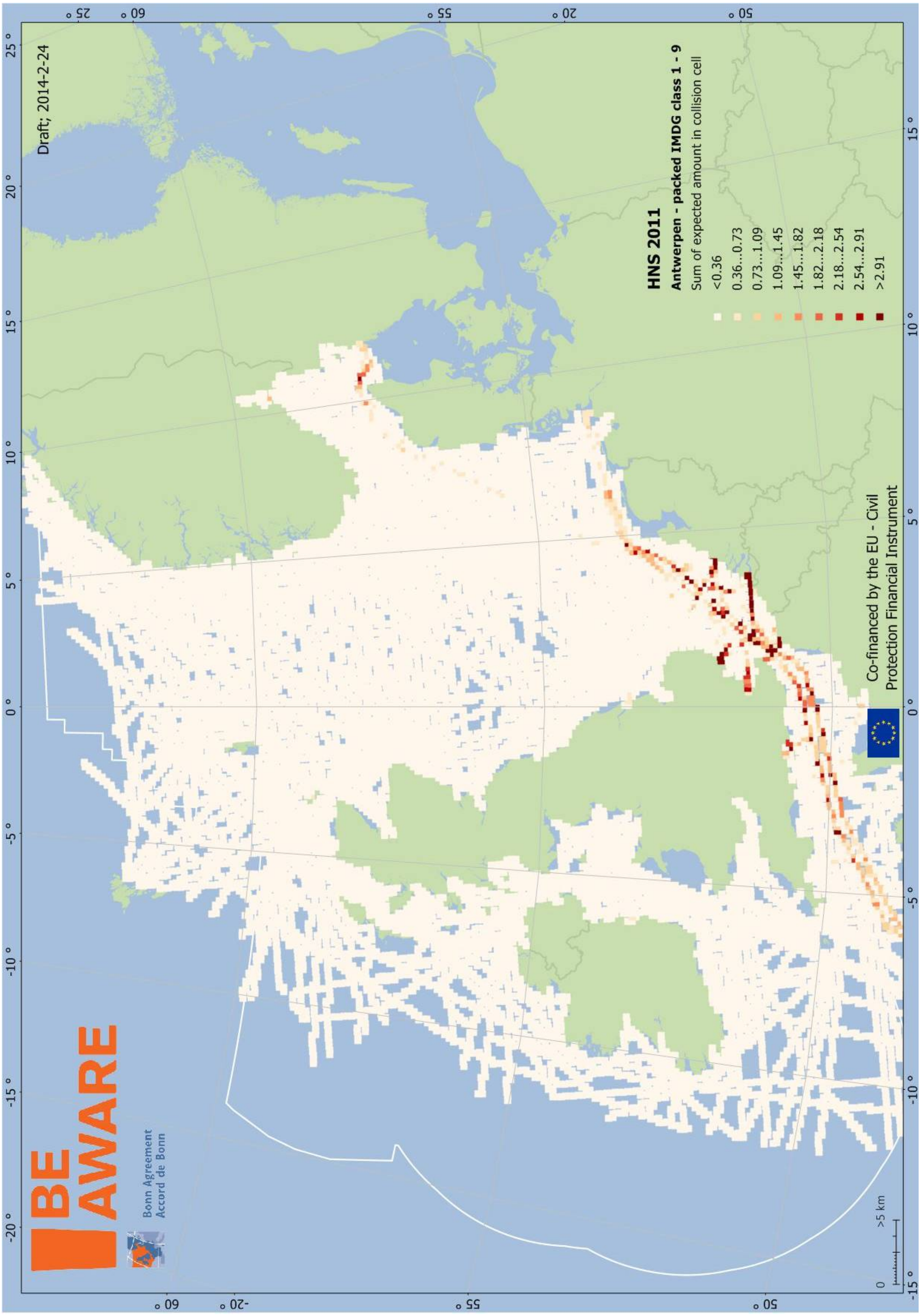
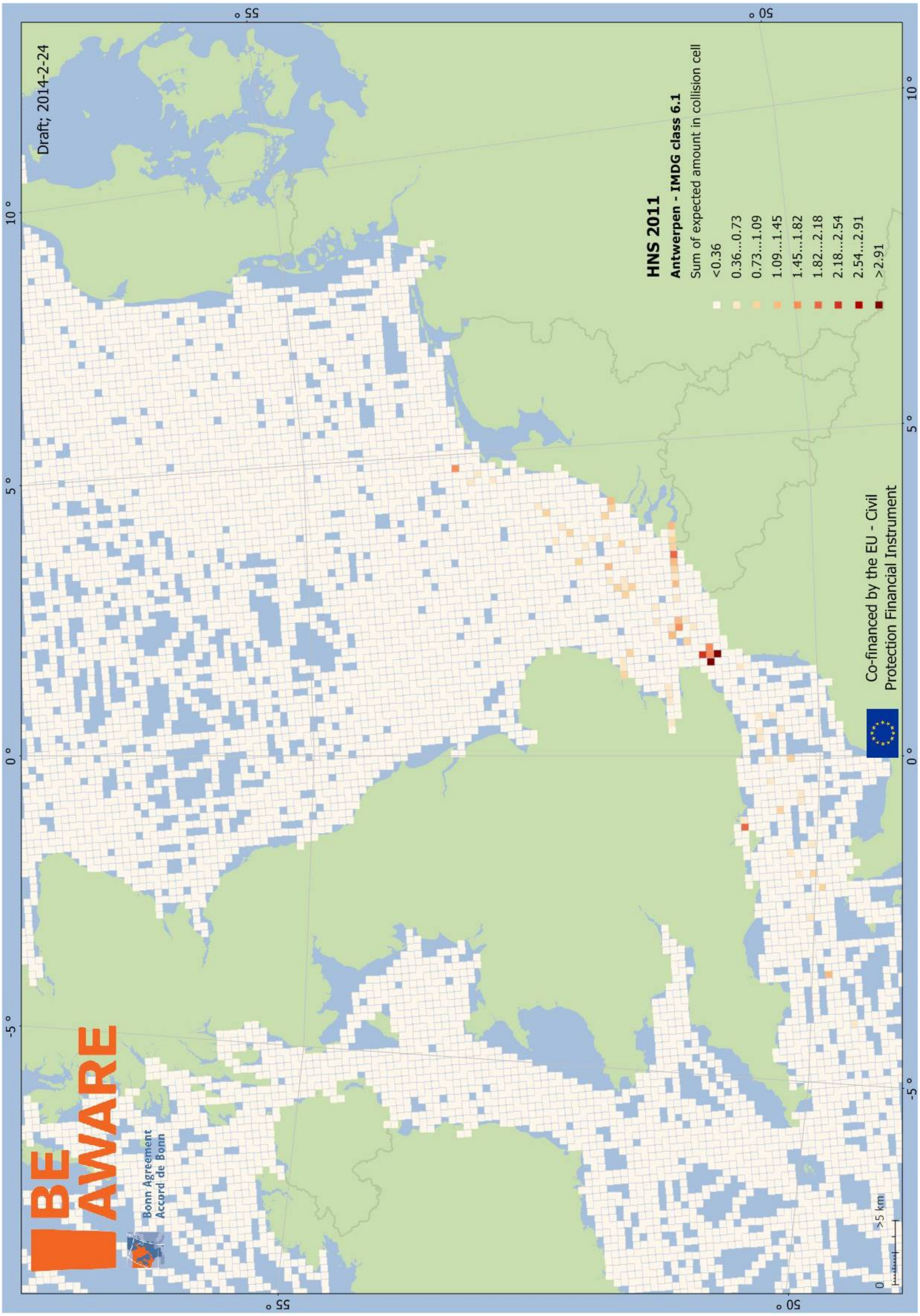


Figure 5-5 Packed goods containing IMDG 6.1 substances involved in collisions (Table 5-6)



Annex 2: Analysis of the complete Rotterdam database (including oil)

Analysis of the Rotterdam database

Apart from the analyses of the HNS data combined with the harmful substances also the complete Rotterdam database has been analysed. The IMDG classification for all substances in the database is shown below.

Table IMDG classification of all substances transported to Rotterdam

All substances Rotterdam, including oil				
IMDG class	Total Rotterdam [t]	Total Rotterdam [%]	Shipments [-]	Shipments [%]
IMDG not linked	6616267	4.82%	5961	39.23%
- (not dangerous)	10084372	7.35%	2092	13.77%
1.3G	4	0.00%	1	0.01%
2	37	0.00%	5	0.03%
2.1	1198737	0.87%	349	2.30%
2.2	187	0.00%	14	0.09%
2.3	142722	0.10%	8	0.05%
3	115281693	83.98%	5360	35.28%
4.1	20525	0.01%	6	0.04%
4.2	700919	0.51%	56	0.37%
4.3	25	0.00%	1	0.01%
5.1	15673	0.01%	5	0.03%
6.1	647338	0.47%	516	3.40%
8	1143378	0.83%	645	4.25%
9	1385386	1.01%	146	0.96%
x (no IMDG-code found)	40709	0.03%	29	0.19%
Total IMDG code	120536625	87.80%	7112	46.81%
Total	137277974	100.00%	15194	100.00%

From this table it can be concluded that the majority of the substances transported to Rotterdam fall in class 3, flammable liquids. Also the ship types used for the transport of the substances has been made, this is shown in the next figure.

Table Ship types used for the transport of cargo to Rotterdam

ShipType	**All substances**	
	[t]	[%]
Bulk / Oil Carrier	2622481	1.91%
Chemical / Oil Products Tanker	43053218	31.36%
Crude Oil Tanker	74462580	54.24%
LPG Tanker	1650107	1.20%
Oil Products Tanker	15223576	11.09%
Vegetable Oil Tanker	266012	0.19%
Totals	**137277974**	**100%**

The amount of cargo involved in collisions is also computed for the complete Rotterdam database, so including oil and HNS. This result is shown in the next table:

Table Amount of substances involved in collisions

Amount involved in collissions (total)				
Class [-]	**Amount [t]**	**Amount [%]**	**Records [-]**	**Records [-]**
Not linked	1284	6.57%	0.14	2.10%
0	1406	7.20%	2.71	40.08%
1.3G	0	0.00%	0.00	0.00%
2	8	0.04%	0.49	7.24%
2.1	575	2.94%	0.10	1.45%
2.2	3	0.01%	0.18	2.60%
2.3	173	0.89%	0.02	0.30%
3	15083	77.22%	1.46	21.55%
4.1	3	0.02%	0.02	0.28%
4.2	225	1.15%	0.01	0.13%
4.3	1	0.00%	0.01	0.13%
5.1	6	0.03%	0.09	1.34%
6.1	83	0.42%	0.29	4.34%
8	163	0.83%	0.69	10.24%
9	512	2.62%	0.55	8.16%
x	7	0.04%	0.00	0.07%
Total	**19532**		**6.76**	
Total IMDG	**16836**		**3.90**	

This table shows that per year 19532 tonnes of cargo is involved in a collision. Each year 6.8 cargo shipments are involved in a collision. The total number of collisions is estimated to be 2.5 per year.

Annex 3: Top 100 transported HNS to Rotterdam (not oil)

	Substance	IMDG class	Total amount [tn]	Shipments [-]	Amount per shipment [tn]
1	METHANOL	3	2264663	164	13809
2	BULKLADING ONDER GAS	9	1277775	54	23662
3	ETHYL ALCOHOL	3	942591	274	3440
4	SEED CAKE	4.2	700705	43	16295
5	SODIUM HYDROXIDE SOLUTION	8	581030	135	4304
6	XYLENES	3	577863	207	2792
7	CALCIUM CARBONATE	-	532906	40	13323
8	PALM OLEIN	-	495355	232	2135
9	METHYL TERT BUTYL ETHER	3	491460	77	6383
10	ETHYL TERT BUTYL ETHER	3	385571	87	4432
11	METHANE	2.1	169647	2	84824
12	PHOSPHORIC ACID	8	164574	34	4840
13	PROPYLENE TRIMER	2.1	156778	84	1866
14	ACRYLONITRILE	3	143823	65	2213
15	ACETONE	3	140296	79	1776
16	VINYL CHLORIDE	2.1	133750	32	4180
17	SULPHURIC ACID	8	132276	22	6013
18	ETHYLENE GLYCOL	-	125935	83	1517
19	PROPYLBENZENE (ALL ISOMERS)		121064	15	8071
20	CYCLOHEXANE	3	120884	26	4649
21	ISOBUTANE	2.1	118728	50	2375
22	NONYL ALCOHOL (ALL ISOMERS)	9	103746	43	2413
23	NITROBENZENE	6.1	103573	55	1883
24	ACETIC ACID	8	101815	31	3284
25	OCTANE (ALL ISOMERS)	3	95840	71	1350
26	BUTADIENE	2.1	94553	48	1970
27	ETHYLBENZENE	3	94441	26	3632
28	AMMONIA NHYDROUS	2.3	91672	5	18334
29	ETHYLENE DICHLORIDE	3	90713	26	3489
30	MIXED AROMATICS		85200	2	42600
31	ADIPONITRILE	6.1	77975	38	2052
32	PROPYLENE OXIDE	3	77104	47	1641
33	MOLASSES	-	76298	14	5450
34	IP EXTRACTION FEED		73375	11	6670
35	PROPANE		72591	12	6049
36	ALKYLATE	-	72585	18	4032
37	DIALKYL (C7-C13) PHTHALATES		72171	58	1244
38	METHYL ETHYL KETONE	3	70560	71	994
39	FORMALDEHYDE SOLUTION	8	69231	76	911
40	BUTANOL	3	67710	35	1935
41	AROMASOL H (ICI)		63000	1	63000
42	BENZENE HEARTCUT		58480	13	4498
43	LIQUIFIED NATURAL GAS		58295	1	58295
44	TALLOW		55036	19	2897
45	NONENE (ALL ISOMERS)	3	54044	33	1638

46	PALM FATTY ACID	-	53415	38	1406
47	ISO PROPYL ALCOHOL	3	52699	76	693
48	REFORMATE		51474	6	8579
49	PHOSPHINE	2.3	51021	1	51021
50	FAME		46572	14	3327
51	BUTYLENE GLYCOL		45730	35	1307
52	WAXES		44706	28	1597
53	VINYL ACETATE	3	44031	19	2317
54	FATTY ACID METHYL ESTER	-	40830	9	4537
55	ETHYL ACETATE	3	35815	30	1194
56	SODIUM METHYLATE SOLUTION		35450	14	2532
57	DIMETHYLPOLYSILOXANE		35055	19	1845
58	GLYCERINE		35053	19	1845
59	ACRYLONITRILE-STYRENE COPOLYMER DISPERSION IN POLYETHER POLYOL	3	34970	65	538
60	ACETIC ANHYDRIDE		34390	23	1495
61	CHLOROFORM	6.1	34125	27	1264
62	ALCOHOLS (C12-C13)		33740	35	964
63	WHITE SPIRIT		32840	15	2189
64	METHYL METHACRYLATE	3	32441	32	1014
65	ISO BUTANOL	3	32360	27	1199
66	CYCLOHEXANONE	3	31698	39	813
67	LOW SULPHER ATMOSPHERIC RESIDUE		31500	1	31500
68	PROPYLENE GLYCOL	-	31425	41	766
69	GLYCEROL PROPOXYLATED AND ETHOXYLATED	-	30452	45	677
70	ESCAID		29940	20	1497
71	DECYL ALCOHOL (ALL ISOMERS)		29151	32	911
72	CALCIUM LIGNOSULPHONATE SOLUTIONS	-	28242	7	4035
73	ISO- AND CYCLO-ALKANES (C12+)		28163	14	2012
74	BUTYL ACRYLATE (ALL ISOMERS)	3	28105	35	803
75	DICHLOROMETHANE		27663	28	988
76	DODECYL ALCOHOL		27176	22	1235
77	OCTAMETHYLCYCLOTETRASILOXANE		26009	14	1858
78	PROPYLENE TETRAMER	3	24995	17	1470
79	DECENE		24909	25	996
80	ETHANOL SOLUTION (ETHYL ACOLHOL SOLUTION)	3	24045	18	1336
81	LARD		22877	7	3268
82	CREOSOTE (COAL TAR)		22650	5	4530
83	PROPYLENE GLYCOL MONO ALKYL ETHER	3	22308	31	720
84	POLYMETHYLENE POLYPHENYL ISOCYANATE		22275	16	1392
85	PERCHLOROETHYLENE		21819	20	1091
86	TERT-BUTYL ALCOHOL		21225	6	3538
87	RAFFINATE		20900	1	20900
88	FORMIC ACID	8	20864	22	948
89	DIPHENYLMETHANE DIISOCYANATE	-	20682	9	2298
90	METHYL ACRYLATE	3	20625	18	1146
91	PARAXYLENE	3	19776	6	3296
92	SODIUM HYDROXIDE SOLUTION		19550	2	9775
93	NAPHTHA	3	19536	3	6512
94	SHEA BUTTER		18752	7	2679
95	2-HYDROXY-4-(METHYLTHIO)BUTANOIC ACID		18691	16	1168
96	HEAVY AROMATICS		18542	6	3090

97	DICHLOROPROPANE		18220	18	1012
98	ACIDE PHOSPHORIQUE SOLUTION		18076	3	6025
99	ZONNEBLOEM PELLETS		18050	1	18050
100	EPICHLOROHYDRIN	6.1	17950	14	1282
	Total (top 100)		13291240	3660	3631
	Total (overall)		14277458	5487	2602

Annex 4: Top 100 most handled substances in Antwerp

Top 100 most handled substances in bulk in Antwerp					
Ranking [-]	Substance [-]	IMDG-code [-]	Amount [t]	Shipments [-]	Amount per shipment [t]
1	FATTY ACID METHYL ESTHER	-	3909513	38	102882
2	PROPANE	2.1	2760875	109	25329
3	ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S.	9	1791825	517	3466
4	PROPYLENE	2.1	1467904	528	2780
5	ELEVATED TEMPERATURE LIQUID, FLAMMABLE, N.O.S. with flashpoint above 60°C, at or above its flashpoint	3	1143287	82	13943
6	METHANOL	3	1072470	97	11056
7	SODIUM HYDROXIDE SOLUTION	8	937324	145	6464
8	HYDROCARBONS, LIQUID, N.O.S.	3	931857	329	2832
9	ACETIC ACID, GLACIAL or ACETIC ACID, SOLUTION, more than 80% acid, by mass	8	917388	250	3670
10	FLAMMABLE LIQUID, N.O.S.	3	786640	342	2300
11	AMMONIA, ANHYDROUS	2.3	723182	61	11855
12	BUTANE	2.1	675434	174	3882
13	ETHYLENE, REFRIGERATED LIQUID	2.1	582067	309	1884
14	ELEVATED TEMPERATURE LIQUID, N.O.S. at or above 100°C and below its flashpoint (including molten metals, molten salts, etc.)	9	533090	212	2515
15	CYCLOHEXANE	3	519083	168	3090
16	ETHYL ACETATE	3	477992	166	2879
17	ACETONE (ACETONE SOLUTIONS)	3	475423	167	2847
18	VINYL ACETATE, STABILIZED	3	467510	203	2303
19		3	396362	45	8808
20	SODIUM HYDROXIDE, SOLID	8	378863	70	5412
21	MONO ETHYLENE GLYCOL	-	376530	117	3218
22	ACETIC ANHYDRIDE	8	363006	143	2539
23	PHENOL, MOLTEN	6.1	333053	163	2043
24	BENZENE	3	324134	71	4565
25	ANILINE	6.1	300835	68	4424
26	BUTANOLS	3	297434	85	3499
27	STYRENE MONOMER, STABILIZED	3	293920	77	3817
28	XYLENES	3	293690	94	3124
29	PHOSPHORIC ACID SOLUTION	8	253542	71	3571
30	ISOPROPYLBENZENE	3	239283	65	3681
31	POTASSIUM NITRATE	5.1	233164	14	16655
32	1-HEXENE	3	224561	101	2223
33	SULPHURIC ACID with more than 51% acid	8	222040	71	3127
34	BUTYLENE	2.1	219439	57	3850
35	ETHANOL (ETHYL ALCOHOL) or ETHANOL SOLUTION (ETHYL ALCOHOL SOLUTION)	3	189860	93	2042
36	ISOPROPANOL (ISOPROPYL ALCOHOL)	3	170646	97	1759
37	BUTYL ACRYLATES, STABILIZED	3	158693	65	2441

38	BUTADIENES, STABILIZED	2.1	157470	109	1445
39	POTASSIUM HYDROXIDE SOLUTION	8	154588	54	2863
40	ETHYL METHYL KETONE (METHYL ETHYL KETONE)	3	151031	79	1912
41	TOLUENE DIISOCYANATE	6.1	126753	49	2587
42	ETHYLENE GLYCOL MONOMETHYL ETHER	3	108911	29	3756
43	CRUDE OIL RUSSIAN BLEND	3	100067	1	100067
44	HYDROCARBON GAS MIXTURE, COMPRESSED, N.O.S.	2.1	99212	71	1397
45	METHYL BUTYL ETHER	3	95915	28	3426
46	ACRYLONITRILE, STABILIZED	3	89431	54	1656
47	FUEL OIL LOW SULPHUR	3	88772	5	17754
48	AMMONIUM NITRATE FERTILIZERS: Uniform non-segregating mixtures of ammoniumnitrate with added matter which is inorganic and chemically inert towards ammonium nitrate, with not less than 90% ofammon-ium nitrate and not more than 0.2% of combustible material	5.1	79475	30	2649
49	CHLOROFORM	6.1	79166	34	2328
50	DIETHYLENE GLYCOL	-	78774	42	1876
51	HEXAMETHYLENEDIAMINE, MOLTEN	8	77051	48	1605
52	ETHANOLAMINE or ETHANOLAMINE SOLUTION	8	75892	38	1997
53	2-ETHYL HEXANOL	-	74116	47	1577
54	PROPYLENE OXIDE	3	69495	19	3658
55	PHENOL SOLUTION	6.1	68180	18	3788
56	DICHLOROMETHANE	6.1	67581	54	1252
57	MEG		66892	24	2787
58	TOLUENE	3	65804	35	1880
59	METHYL ACRYLATE, STABILIZED	3	61220	21	2915
60	METHYLAMYL ACETATE	3	60000	1	60000
61	POTASSIUM HYDROXIDE, SOLID	8	59188	14	4228
62	OLEFINS	-	57215	33	1734
63	NITRIC ACID other than red fuming, with at least 65% but with not more than 70% nitric acid	8	56315	28	2011
64	ETHYLENE GLYCOL MONOETHYL ETHER	3	52992	9	5888
65	FORMIC ACID with more than 85% acid, by mass	8	52821	49	1078
66	METHYL ISOBUTYL KETONE	3	49047	34	1443
67	METHYL METHACRYLATE, MONOMER, STABILIZED	3	48899	39	1254
68	SULPHUR, MOLTEN	4.1	48258	8	6032
69	PETROLEUM GASES, LIQUEFIED	2.1	46210	6	7702
70	FURALDEHYDES	6.1	44154	10	4415
71	PROPIONIC ACID - (PSN amdt 32)	8	40585	51	796
72	DICYCLOPENTADIENE	3	40494	17	2382
73	CRUDE OIL	3	40000	1	40000
74	ISOBUTYLENE	2.1	39440	32	1233
75	TARS, LIQUID including road oils, and cutback bitumens	3	37519	18	2084
76	ISOBUTANOL	3	36190	27	1340
77	PROPYLENE TETRAMER	3	35840	25	1434
78	KAOLINE		35239	1	35239
79	MONO ETHYLENE GLYCOL FIBER		34188	11	3108
80	LUBOIL	-	33050	14	2361
81	CYCLOHEXANONE	3	33029	10	3303
82	ULTRA LOW SULPHUR DIESEL 10 PPM	3	33000	1	33000
83	ADIPONITRILE	6.1	32218	22	1464

84	TURPENTINE SUBSTITUTE	3	30691	44	698
85	ETHYLENE DICHLORIDE	3	30500	5	6100
86	MDI		30480	10	3048
87	HYDROCARBON GAS MIXTURE, LIQUEFIED, N.O.S.	2.1	30343	19	1597
88	CRUDE TALL OIL	-	28411	3	9470
89	S-OILS		27642	2	13821
90	SODIUM NITRATE	5.1	27450	8	3431
91	EPICHLOROHYDRIN	6.1	26377	11	2398
92	DIMETHYL LINEARS		26071	10	2607
93	STAR 2		26044	12	2170
94	CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S.	8	26016	89	292
95	base oils	-	25628	8	3204
96	TETRACHLOROETHYLENE	6.1	25397	26	977
97	CASTOR OIL		25144	8	3143
98	ISOSIR		23524	18	1307
99	GLYCOLS		23386	6	3898
100	ETHYL ACRYLATE, STABILIZED	3	23340	21	1111
	Total (top 100)		28980050	7114	
	Total (all)		31683737	12408	2553

Top 100 most transported packed goods to Antwerp					
Ranking	Substance	IMDG-code	Amount [t]	Shipments [-]	Amount per shipment [t]
1	ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S.	9	1060071	6265	169
2	POTASSIUM NITRATE	5.1	1050249	582	1805
3	SODIUM CARBONATE PEROXYHYDRATE	5.1	1025509	536	1913
4	ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S.	9	770409	6455	119
5	DIMETHYLAMINE, AQUEOUS SOLUTION	3	692573	156	4440
6	TOLUENE DIISOCYANATE	6.1	658522	1035	636
7	ETHYL METHYL KETONE (METHYL ETHYL KETONE)	3	526296	385	1367
8	ACETONE (ACETONE SOLUTIONS)	3	484475	642	755
9	FERROUS METAL BORINGS, SHAVINGS, TURNINGS, or CUTTINGS in a form liable to self-heating	4.2	449548	9	49950
10	SODIUM HYDROXIDE, SOLID	8	371177	1151	322
11	DICHLOROMETHANE	6.1	265173	1091	243
12	PHOSPHORIC ACID SOLUTION	8	251056	1558	161
13	SODIUM CHLORATE	5.1	190367	352	541
14	WHITE ASBESTOS (chrysotile, actinolite, anthophylite, tremolite)	9	183287	195	940
15	ISOPROPANOL (ISOPROPYL ALCOHOL)	3	173999	1249	139
16	FLAMMABLE LIQUID, N.O.S.	3	173054	4821	36
17	SODIUM NITRATE	5.1	154657	233	664
18	RESIN SOLUTION flammable	3	133712	3540	38
19	BATTERIES, WET, FILLED WITH ACID electric storage	8	124978	2647	47
20	PAINT or PAINT RELATED MATERIAL	3	117904	4479	26
21	ETHANOL (ETHYL ALCOHOL) or ETHANOL SOLUTION (ETHYL ALCOHOL SOLUTION)	3	111719	2473	45
22	SODIUM METHYLATE SOLUTION in alcohol	3	108295	271	400
23	TOXIC SOLID, INORGANIC, N.O.S.	6.1	103520	770	134
24	HYDROGEN PEROXIDE, AQUEOUS SOLUTION with not less than 20% but not more than 60% hydrogen peroxide (stabilized as necessary)	5.1	101884	869	117
25	AEROSOLS	2	101211	5058	20
26	TETRAHYDROFURAN	3	98428	351	280
27	HYDROGEN PEROXIDE, STABILIZED or HYDROGEN PEROXIDE, AQUEOUS SOLUTION, STABILIZED with more than 60% hydrogen peroxide	5.1	98319	220	447

28	FISHMEAL (FISHSCRAP), STABILIZED Anti-oxidant treated. Moisture content greater than 5% but not exceeding 12% by mass. Fat content not more than 15%	9	94623	200	473
29	CORROSIVE LIQUID, BASIC, ORGANIC, N.O.S.	8	93582	1575	59
30	CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S.	8	90078	2682	34
31	TETRACHLOROETHYLENE	6.1	89221	607	147
32	TOXIC LIQUID, ORGANIC, N.O.S.	6.1	77070	1335	58
33	PERFUMERY PRODUCTS with flammable liquid	3	71773	3574	20
34	HYDROCHLORIC ACID	8	69375	984	71
35	BARIUM COMPOUND, N.O.S.	6.1	68555	406	169
36	CYCLOHEXANONE	3	67166	238	282
37	ETHYL ACETATE	3	65067	638	102
38	SODIUM CYANIDE, SOLID	6.1	59366	290	205
39	SODIUM SULPHIDE, HYDRATED with not less than 30% water	8	54603	256	213
40	CORROSIVE LIQUID, TOXIC, N.O.S.	8	54253	1282	42
41	NAPHTHALENE, MOLTEN	4.1	53511	120	446
42	FUMIGATED UNIT	9	53216	330	161
43	DISODIUM TRIOXOSILICATE	8	51857	372	139
44	AMMONIUM NITRATE with not more than 0.2% combustible substances including any organic substance calculated as carbon to the exclusion of any other added substance	5.1	50856	361	141
45	FERROSILICON with 30% or more but less than 90% silicon	4.3	49651	152	327
46	HYPOCHLORITE SOLUTION	8	49506	582	85
47	TOLUENE	3	49114	451	109
48	BROMINE or BROMINE SOLUTION	8	48518	319	152
49	NITRIC ACID other than red fuming, with at least 65% but with not more than 70% nitric acid	8	46942	539	87
50	ALCOHOLIC BEVERAGES, with more than 24% but not more than 70% alcohol by volume	3	46275	636	73
51	CORROSIVE LIQUID, N.O.S.	8	46228	2665	17
52	CARBON DISULPHIDE	3	45995	143	322
53	POLYMERIC BEADS, EXPANDABLE evolving flammable vapour	9	44895	733	61
54	ORGANOPHOSPHORUS PESTICIDE, SOLID, TOXIC	6.1	43964	140	314
55	HEXAMETHYLENETETRAMINE	4.1	42776	195	219
56	FLAMMABLE LIQUID, TOXIC, N.O.S.	3	39857	772	52
57	2,4-TOLUYLENEDIAMINE, SOLID	6.1	38400	158	243
58	SULPHUR	4.1	38373	108	355
59	FORMIC ACID with more than 85% acid, by mass	8	35653	715	50
60	ALUMINIUM CHLORIDE, ANHYDROUS	8	34536	205	168

61	ETHYLENEDIAMINE	8	32064	343	93
62	SODIUM DITHIONITE (SODIUM HYDROSULPHITE)	4.2	31352	445	70
63	EPICHLOROHYDRIN	6.1	30275	272	111
64	EXTRACTS, FLAVOURING, LIQUID	3	28512	1930	15
65	AMINES, LIQUID, CORROSIVE, N.O.S. or POLYAMINES, LIQUID, CORROSIVE, N.O.S.	8	27080	2327	12
66	HEXANES	3	25538	317	81
67	SODIUM NITRITE	5.1	24918	355	70
68	CHROMIUM TRIOXIDE, ANHYDROUS	5.1	24654	376	66
69	ACRYLIC ACID, STABILIZED	8	21779	230	95
70	MALEIC ANHYDRIDE, MOLTEN	8	20619	213	97
71	ALCOHOLS, N.O.S.	3	20098	1212	17
72	SODIUM HYDROXIDE SOLUTION	8	19224	1431	13
73	METHYL METHACRYLATE, MONOMER, STABILIZED	3	19035	393	48
74	OXIDIZING SOLID, N.O.S.	5.1	18720	644	29
75	ADHESIVES containing flammable liquid	3	18583	2498	7
76	ORGANOMETALLIC SUBSTANCE, LIQUID, PYROPHORIC, WATER-REACTIVE	4.2	18223	562	32
77	TERPENE HYDROCARBONS, N.O.S.	3	17029	686	25
78	SODIUM HYDROSULPHIDE, HYDRATED with not less than 25% water of crystallization	8	16588	156	106
79	AMINES, LIQUID, CORROSIVE, FLAMMABLE, N.O.S. or POLYAMINES, LIQUID, CORROSIVE, FLAMMABLE, N.O.S.	8	16212	564	29
80	TETRAFLUOROETHANE(REFRIGERANT GAS R 134a)	2.2	16092	633	25
81	CHLOROACETIC ACID, SOLID	6.1	15735	108	146
82	LEAD COMPOUND, SOLUBLE, N.O.S.	6.1	15610	416	38
83	PARAFORMALDEHYDE	4.1	15242	220	69
84	FLAMMABLE SOLID, ORGANIC, N.O.S.	4.1	15043	1166	13
85	ETHANOLAMINE or ETHANOLAMINE SOLUTION	8	15003	544	28
86	TOXIC SOLID, ORGANIC, N.O.S.	6.1	14904	971	15
87	PENTAFLUOROETHANE (REFRIGERANT GAS R 125)	2.2	14797	179	83
88	POTASSIUM HYDROXIDE, SOLID	8	14404	393	37
89	ELEVATED TEMPERATURE LIQUID, N.O.S. at or above 100°C and below its flashpoint (including molten metals, molten salts, etc.)	9	14233	223	64
90	BENZYL CHLORIDE	6.1	14032	277	51
91	HYDROGEN FLUORIDE, ANHYDROUS	8	14003	166	84
92	ARGON, REFRIGERATED LIQUID	2.2	13980	260	54
93	CAUSTIC ALKALI LIQUID, N.O.S.	8	13844	1111	12
94	SELF-HEATING SOLID, ORGANIC, N.O.S.	4.2	13321	190	70
95	ETHYL MERCAPTAN	3	12940	274	47
96	BENZOYL CHLORIDE	8	12431	428	29

97	CYANURIC CHLORIDE	8	11964	141	85
98	CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S.	8	11628	1392	8
99	SULPHAMIC ACID	8	11371	365	31
100	AMMONIUM NITRATE FERTILIZERS: Uniform non-segregating mixtures of nitrogen/phosphate or nitrogen/potash types or complete fertilizers of nitrogen/phosphate/potash type, containing not more than 70% of ammonium nitrate and not more than 0.4% of total added	9	11371	88	129
	Total (top 100)		12167698	95655	127
	Total (all)		13198219	167721	79