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puh. vaihde 020 722 111, faksi 020 722 4374

VTT, Bergsmansvägen 3, PB 1000, 02044 VTT
tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 3, P.O.Box 1000, FI-02044 VTT, Finland
phone +358 20 722 111, fax + 358 20 722 4374

VTT, Otakaari 7 B, PL 1000, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 7076

VTT, Otsvängen 7 B, PB 1000, 02044 VTT
tel. växel 020 722 111, fax 020 722 7076

VTT Technical Research Centre of Finland, Otakaari 7 B, P.O. Box 1000, FI-02044 VTT, Finland
phone internat. +358 20 722 111, fax +358 20 722 7076

Chemical tanker Acushnet during salvage operation. Photograph courtesy of the International Salvage Union.

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Abstract

While gathering information about oil transportation for VTT Publication 547, *Oil transportation and terminal development in the Gulf of Finland* (2004), the question about other harmful substances transported in liquid bulk was raised. The Finnish Ministry of the Environment, Finnish Environment Institute (SYKE) and Finnish Maritime Administration (FMA) have made it possible for us to continue the work on tanker transportations by financing this study. The area has been widened to cover the entire Baltic Sea. This publication introduces the statistics concerning the chemicals handled in liquid bulk in the Baltic Sea ports in 2004. The data is based on the public registers, data files and announcements of port authorities and operators. A special questionnaire on transported chemicals, and specifically on bulk form chemicals, was made for ports. Some of the ports have expressed their concern about giving what they consider to be sensitive information; alas, the data in this publication is not to be considered full and complete, but it does give an indication of where chemical tankers are sailing.

The latest comprehensive study about chemical transportations in the Baltic Sea was made by HELCOM in 1990 (*Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area*). HELCOM statistics were gathered by a thorough collection of data in all Baltic Sea ports during the entire year of 1987. Unfortunately, this specific and time-consuming means of data acquisition was impossible with this publication due to the time scale of the project.

Some of the most dangerous or most common chemicals were selected and briefly analysed on the basis of their environmental impact if released into the water. The risk of chemical outflow has also been discussed within the collision and grounding modes. A special chapter related to the Northern Baltic waters

has been written on the risk of winter navigation for chemical transportation. Discussion has also been carried out on the fate of chemicals spilled on water and on the physical fundamentals when trying to control them; finally, some scenarios are presented on potentially high-risk areas.

Marine chemical transportation is constantly growing in regard of the number of chemicals and the total volume of goods transported. Today, the number of different substances and compounds is quoted in thousands. A great many of these chemicals are dangerous to the environment, and even though the risk of a chemical accident is considered small due to very high standards regarding safety, it does exist. Even if chemical tankers do take safety aspects into consideration, there are a number of other ships in the same sea area, as well as a number of ships crossing their paths and meeting each other in narrow sounds or in dense traffic areas.

The safety practices of chemical tankers are among the best. Maritime society has also introduced several new actions to improve maritime safety. It is a well known fact that the number of large scale oil and chemical spills has declined during the last decades. This fact shows that recent measures such as phase out of single hull tankers, stricter legislation, IMO actions, Erika packages, etc. have improved the safety of ships and routes. However, around 80% of all incidents and accidents are due to the human factor, for example human/machine interaction or cultural behaviour. Thus even though new technical means (VTS, AIS, ECDIS, etc.) have been established to improve safety, there is a lot of work to be done to prevent accidents and environmental damage.

Preface

Dear reader,

In 2004 the Ministry of the Environment of Finland commissioned a report on *Oil transportation and terminal development in the Gulf of Finland*, which was published in 2004 by VTT Technical Research Centre of Finland. The report showed that the oil transportation in the Gulf of Finland is increasing dramatically. In the year 2000 the volume of the oil transported on the Gulf of Finland was 40 million tonnes, in 2004 the amount was anticipated to reach 100 million tonnes, and the estimate for 2010 is that the volume will rise up to 190 million tonnes.

Furthermore, the report showed clearly that not only oil transportation but also all types of maritime transport are growing in the Baltic Sea area. As traffic volumes continue to rise, the risk of accidents is also increasing. Any accident involving ships transporting harmful substances, be they oil or chemicals, poses a threat to the vulnerable nature of the Baltic Sea, and must be seen as a serious environmental risk.

To plan the prevention of and the preparedness for accidents involving harmful substances, updated information on all aspects of transport is required. This takes into account information on what substances are handled, in what amounts and on what routes these chemicals are transported.

The publication encompasses statistics about the chemicals transported in liquid bulk in the Baltic Sea area in 2004. The data have been gathered from the main ports of the Baltic Sea. This statistical information is an important complement to the general impression of the transport – its volumes and future trends – in the Baltic Sea.

However, one of the main results of this study is that the quality and amount of the information available from the ports varies a lot. Additionally, many ports are reluctant to give information on the chemicals transported. This means that even after this study we cannot say that our statistics on the transport of chemicals in liquid bulk on the Baltic Sea are comprehensive – which sets alarm bells ringing. The handling of chemicals is a very demanding task, and if an accident occurs, information on the amounts and characteristics of the chemicals should be immediately available.

Maritime safety in the Baltic Sea has improved in recent years due to decisions made at the global and regional level. The Gulf of Finland mandatory Ship Reporting System (GOFREP) came into operation in 2004, and it has been estimated that this system will reduce the risk of collision between two vessels by 80 per cent. In 2005 HELCOM (the Baltic Marine Environment Protection Commission) launched an Automatic Identification System (AIS). The AIS enables all the coastal countries to receive information on the vessels passing through national waters, and all the ships to identify each other at sea.

In addition to concentrating on efforts to secure maritime safety in the Baltic Sea, it is important to enhance the cooperation on the preparedness for accidents. This publication shows clearly the deficiencies in the current system in providing the needed information to the authorities on the transport of chemicals. Accurate information is crucial when designing response actions to prevent the environment from becoming polluted.

Jan-Erik Enestam
Minister of the Environment of Finland

Photo by Dick Lindberg

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The members in the project's control group have all been of great help when defining the objective and contents of the study, as well as during the work itself. The members of the group were: Olli Pahkala and Miliza Malmelin from the Ministry of the Environment (YM), Taneli Antikainen and Jyrki Vähätalo from the Finnish Maritime Administration (FMA), Kalervo Jolma from the Environment Institute (SYKE) as well as the authors of the publication, Jorma Rytkönen and Saara Hänninen from VTT. Also Martti Poutanen and Henna Haapala from YM and Kari Lampela, Timo Seppälä, Tuula Kuusela and Arto Kultamaa from SYKE have attended the meetings and given their valuable contribution to the study.

We thank HELCOM Maritime for supporting the study and for help in gathering statistics from the ports. Thanks to Hanna Paulomäki who helped us with the maps. We thank Lasse Rikala from Crystal Pool for valuable comments and for proofreading the publication. Special thanks to all the officials from ports and maritime administrations who answered our questionnaire about transportation statistics.

Contents

1. Introduction

During the last decade shipping has steadily increased around the Baltic Sea. Around 2,000 sizeable ships are normally at sea at any time in the Baltic, including large oil tankers, ships carrying dangerous and potentially polluting cargoes, and many large passenger ferries. The Baltic Sea has some of the busiest shipping routes in the world.

In 2004, VTT published a study called *Oil transportation and terminal development in the Gulf of Finland* on assignment by the Finnish Ministry of the Environment. The publication (Hänninen & Rytkönen, 2004) covers statistics on oil transport in the area and discusses future terminal development. During the project, the question about chemical transportations in the Gulf of Finland and in the Baltic Sea as a whole came up several times. HELCOM has studied it in *Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area* (HELCOM, 1990), but the statistics used are from 1987 and need to be updated.

According to the level of 1987 a total of about 5.8 million tons of liquid chemicals and 2.9 million tons of gases were transported in the Baltic Sea. In total, the transported amount of chemicals belonging to categories A to D in the MARPOL Class was equivalent to about 2,400 million tonmiles. This corresponds to about 12 loaded tankers being en route in the Baltic Sea at any given time (HELCOM, 1990).

The report (HELCOM, 1990) also gave draft risk estimation for the outflow of chemical tankers and concluded that this damage is mainly due to groundings and collisions. The outflow of cargo from a single bottom chemical tanker was estimated to be 25 in 100,000 voyages in a grounding accident. In a collision accident, the corresponding risk was estimated to be 5 in 100,000 voyages. However, these estimations all concerned single hull tankers, and some correction factors were used to convert the results so that they can be applied to double hull tankers. In groundings, single hull tankers were observed to have a spill 8 times more often than double hull tankers. As regards collisions it was observed that for double hull tankers only 20% of the collisions will lead to damage where the inner bulkhead is ruptured and about 20% of these incidents may extend below the waterline. More detailed numbers for the different scenarios have been presented in (HELCOM, 1990).

The results showed that chemical tankers sailing along the narrow and shallow Baltic waters encounter twice as many incidents as tankers sailing in ocean waters. The explanation may be that most of the ships sailing in the Baltic Sea must negotiate narrow shipping lanes, harbour approaches, etc., while tankers sailing across the ocean spend most of their time in deep waters without any danger of groundings.

When studying the risks in the Baltic Sea a rule of thumb is that during 2001–2004 around 50–60 accidents take place annually in the area. The statistics of (HELCOM, 2001) show 251 ship accidents for the period 1989–1999, with accidents mostly occurring near straits and port areas. It should be noted that in the case of some of the countries reporting to HELCOM, the numbers include also the accidents of small fishing vessels. Some parties did not report any accidents, while others reported only tanker accidents. Thus the database behind the report does not give a true picture of the distribution of incidents but mainly shows hot spots and areas with a greater risk of groundings and/or collisions.

Marine pollution from single hull tankers was more frequent than that from double hull tankers. Thus when examining the latest HELCOM reports on shipping accidents now and in the period 1989–1999 it can be noted that there is an increase of incidents, mainly due to increased shipping activities. The higher number of incidents, however, has not led to large scale chemical spills. The data for the years 1989–1999 also contains 30 tanker accidents. However, when analysing the database of the report, other than oil accidents (four cases) included ammonium phosphate and orthoxylen accidents and two cases involving unidentified chemicals. The amount of chemicals spilled was rather small but in many of the reported cases the type of pollution was unknown.

In spite of the fact that the number of liquid chemical transportations along the Baltic Sea is at least 10...20 times smaller than the number of oil transportations now, chemical tankers will meet more and more vessels during their voyage in the Baltic Sea. Oil transportations alone are growing significantly, and their volume in the environment of the Gulf of Finland may exceed 200 million tons prior to the year 2010 (Hänninen & Rytkönen, 2004).

There are a lot of new options for improving safety, some based on new EU legislation (for example the Erika packages), and some based on modern telematic solutions. VTS systems have been established for the Baltic Sea area, providing more reliability for shipping. The new HELCOM AIS will also enhance the possibility to follow and guide maritime traffic. After the accident of the MT Baltic Carrier in the Danish Straits in 2001, a set of new recommendations have been made by HELCOM. Routeing, pilotage, AIS and winter related subjects have been discussed in various expert forums of HELCOM.

Marine chemical transportation is constantly growing in regard of the number of chemicals and the total volume of goods transported. Today, the number of different substances and compounds is quoted in thousands. A great many of these chemicals are dangerous to the environment. Maritime transport of hazardous substances can be done either in bulk or in packaged form. Products in bulk are transported either by chemical carriers, as is the case with liquid substances at an ambient temperature, or by gas carriers if gaseous substances are involved. Tankers transporting chemicals carry a whole range of products, which often pose a number of problems in the case of accidents. The capacity of tankers for chemical products varies from 400 m^3 to 40,000 m^3, and that of tanks varies from 70 m^3 to 2,000 m^3 (Bonn Agreement, 1999).

Sea transportation is often seen as the largest risk in the chemical transportation chain. The fact that chemical tanker accidents are rare compared to oil tanker accidents even on the world scale is mainly due to the difference in transport volume and also to the very high standards regarding safety. The overall development trend of maritime traffic is heavy growth, which means more ships, new routes and a lot of potential areas for groundings and/or collisions. Chemical tankers in the Baltic Sea are not in bad shape, but the volume of chemical traffic has grown remarkably. The greatest challenge is the control of traffic.

This publication introduces the statistics for chemicals handled in liquid bulk in Baltic Sea ports in 2004. Some of the ports have expressed their concern about giving what they consider to be sensitive information; alas, the data in this publication is not to be considered full and complete, but it does give an indication of where chemical tankers are sailing.

2. Environmental issues

2.1 Geography of the Baltic Sea

The Baltic Sea is located in Northern Europe, bounded by the Scandinavian Peninsula, the mainland of Eastern Europe and Central Europe, and the Danish islands. It drains into the Kattegat by way of the Öresund, the Great Belt and the Little Belt. Kattegat then continues in the Skagerrak into the North Sea and the Atlantic Ocean. The Baltic Sea is linked to the White Sea by the White Sea Canal and directly to the North Sea by the Kiel Canal.

The current surface area of the Baltic Sea is approximately 420,000 km^2, its volume is 21,000 km^3. The extent of its catchment area exceeds 1,700,000 km^2. Therefore, the catchment area is approximately five times as large as the surface area itself. The average depth of the Baltic Sea is just 55 m, compared to other landlocked seas such as the Mediterranean whose average depth is 1,000 m. The greatest depth of the Baltic Sea is only 450 m. A total of nine countries border the sea: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, and Sweden.

2.2 Environment

The Baltic Sea is the largest brackish water basin in the world. Its water is a mixture of salty water from the ocean and fresh water supplied by numerous rivers. In the Southern Baltic Sea salinity is as high as 20 parts per thousand, but in the Northern Baltic Sea it is as low as six ppt. The water is almost fresh in river estuaries, for example near St. Petersburg.

The exchange of water in the Baltic Sea is very slow, and if harmful substances are introduced they will remain there for a very long time. The Baltic Sea is connected to the North Sea through narrow and shallow sounds between Denmark and Sweden. It takes 25–35 years for all the water from the Baltic Sea to be replenished by water from the North Sea and beyond.

The environmental conditions of the Baltic Sea are defined by the fresh water input from rivers and precipitation, and by the limited inflow of more saline water from the North Sea. Without the constant, albeit small, influx of saline water through the Danish straits, the Baltic Sea would have been transformed into a gigantic fresh water lake long ago. A clear salinity gradient exists from the almost oceanic conditions in the northern Kattegat to the almost fresh water conditions in the Northern Bothnian Bay.

A salinity barrier also exists between the surface and the seabed of the Baltic. Saline water, naturally heavier than fresh water, flows along the bottom of the sea. The fresh water on the surface of the sea does not mix appreciably with the saline water underneath. As a result, a marked stratification of salinity exists throughout the Baltic Sea at a depth of about 40–70 metres. The salinity barriers prevent the exchange of substances, i.e., oxygen, nutrients, and pollutants, between the two layers. The environmental conditions between the two layers are, thus, vastly different.

Due to the limited water exchange, oxygen poor water predominates near the bottom of many parts of the Baltic Sea. Bacteria growing in this oxygen deficient water break down organic matter and release hydrogen sulphide, a toxic gas. Both the oxygen deficiency and the hydrogen sulphide production combine to make the bottom of the Baltic Sea virtually lifeless. The size of the seabed with impaired conditions varies from year to year and may reach 100,000 km^2 (1/4 of the Baltic Sea).

Only major deep-water inflows that bring large volumes of oxygen-rich water into the Baltic Sea can improve the living conditions in the deeper bottom layers. These inflows are, unfortunately, quite rare. In January 1993, a major deep-water inflow occurred after 16 years of stagnation. But it was only an isolated event. Since 1995 the conditions in deep water have again started to stagnate. In 2003, another inflow occurred but it was not as strong as the one ten years earlier.

2.3 European classification system of chemicals

Chemicals spilled into the sea behave in different ways depending on their properties and environmental conditions. In principle, chemicals can evaporate, float, dissolve or sink when released into the sea. In reality, their behaviour is often more complex, and a chemical may simultaneously for example evaporate into the air and dissolve into the water. Based on the physical properties of chemicals (physical state, density, vapour pressure, solubility), their behaviour after a spill can be predicted. When listing chemicals transported by sea it is therefore advantageous to classify them in different groups according to their physical properties, each group showing similar behaviour in water.

The European Classification System has been initially elaborated to classify chemicals according to their physical behaviour when spilled into the sea. The classification system covers gaseous, liquid and solid chemicals. The purpose of the system is to arrange chemicals in property groups, so that chemicals in the same group show similar physical behaviour in water and could be responded to in a similar way. The chemicals are classified into the following 12 groups on the grounds of basic characterisation (evaporators, floaters, dissolvers and sinkers) and other details regarding physical properties (Table 1).

Table 1. The 12 property groups of chemicals (Bonn Agreement, 2000).

Main group		**Subgroup**	
G	Gas	GD	gas/dissolver
E	Evaporator	ED	evaporator/dissolver
F	Floater	FE	floater/evaporator
		FD	floater/dissolver
		FED	floater/evaporator/dissolver
D	Dissolver	DE	dissolver/evaporator
S	Sinker	SD	sinker/dissolver

The property groups are presented in Appendix A with behaviour descriptions and a few examples of chemicals. The physical behaviour of chemicals in the sea is presented in Figure 1.

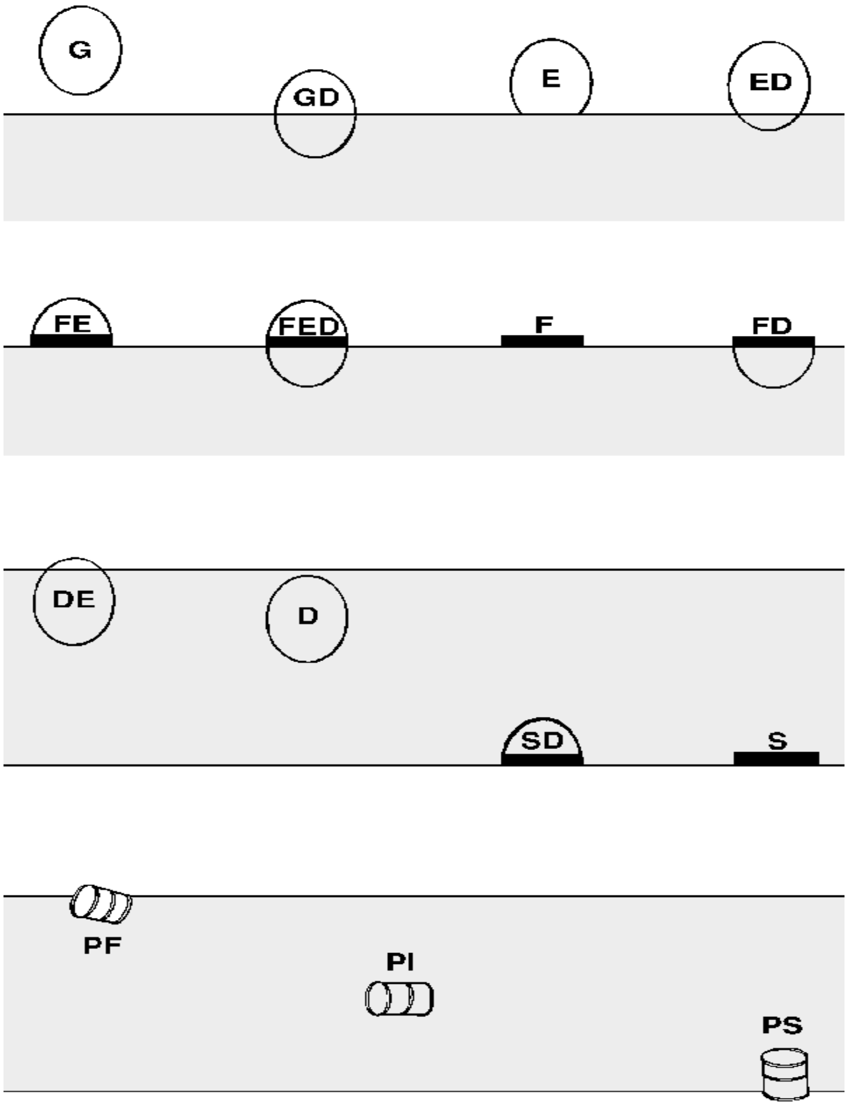

Figure 1. Physical behaviour of chemicals spilled into the sea (Bonn Agreement, 2000).

Grouping of chemicals by physical properties

The property groups of the system are defined according to the state of the substance (gas, liquid, solid) by certain limits of vapour pressure, density, solubility and viscosity (for liquid substances).

Physical state of the substance

Gases are chemicals that boil below ambient temperature at normal atmospheric pressure of 100 kPa. Gases are divided into groups G and GD. They are usually carried at sea in liquefied form. Liquids are chemicals that boil above ambient temperature at 100 kPa, but melt below ambient temperature. Solids are chemicals that melt above ambient temperature at 100 kPa. Liquids and solids are divided into the different groups either as evaporators (E, ED), floaters (F, FE, FED, FD), dissolvers (D, DE) or sinkers (S, SD).

Density

The relative density related to seawater makes it possible to know whether a substance floats or not. The density of seawater may affect the floating/sinking behaviour of a chemical with low solubility and a density slightly above 1. During normal temperature conditions the density of the Baltic Sea Area surface waters, e.g., increases from 1.002 in the Northern part of the Gulf of Bothnia to 1.006 in the Baltic Sea Proper, 1.01 in the northern Sound, 1.02 off the Skaw, 1.025 in the Skagerrak and 1.03 in the ocean.

Vapour pressure

Vapour pressure is only used for liquid substances. Below 0.3 kPa a floating substance does not evaporate and over 3 kPa evaporation is fast. A dissolved substance evaporates if the vapour pressure is higher than 10 kPa.

Solubility

The adopted criteria of solubility are different according to the physical state of the substance. Substances are considered insoluble when solubility is less than

0.1% for liquids and 10% for solids. The dissolving process is predominant over a solubility of 5% for liquids and 100% (totally miscible) for solids.

Viscosity

The viscosity parameter is used to differentiate between the liquid floaters, floating products unfavourable for rapid evaporation or dissolving (F) whose viscosity is less than 10 cSt, and floating products forming a persistent slick (Fp) whose viscosity is higher than 10 cSt.

The method of classifying chemicals by physical property limits is shown in the flow diagram of the European classification system in Appendix B. Using this classification system, contingency planning and preparedness for actions against outflows of chemicals can be simplified. The tables in Appendix C show brief overviews of response methods regarding forecast, monitoring and combating. (Bonn Agreement, 2000.)

Grading into the property groups relates only to the respective chemical alone. Chemical tankers carry several different chemicals at the same time, and in case of an accident these may mix and the behaviour of the new compounds may differ from the behaviour of the original chemicals. Unfortunately, it is not possible to go deeply into this problem within this study. Reference GESAMP (2002) highlights the revised standards for the hazard evaluation procedure.

Those chemicals that after an accident do not dissolve into the water but remain afloat can be collected from the water. The statistics for the sea transportation of hazardous liquid chemicals through Baltic ports also mention many chemicals that will sink if spilled into the water. The recovery of such chemicals out of the sea may be conducted only by dredging.

Packed chemicals are not studied in this publication. Combating those once they have spilled into the sea differs from combating bulk chemicals. If the package is undamaged the combating measures include detecting and collecting the chemical packages. If the package is broken, the combating is carried out as when combating chemical bulk.

3. Marine chemical transportation

3.1 General development

Chemicals were once carried around the world as deck cargo in drums and glass carboys on conventional ships, stowed near the rail so they could be easily jettisoned if harmful substances started to leak over the deck or fire broke out, and never carried in the holds. A wide range of ordinary items are in fact derived from complex chemical processes, and are often derived from the by-products of the production of energy. Many of the changes in everyday life that have taken place during the last fifty years have resulted from developments in the chemical industry. Chemical shipments started to grow substantially, with more demanding products, and this in turn has led to the development of specialized ships in which to carry them.

Chemical carriers are highly sophisticated ships with the most complex vessels able to carry up to sixty different types of chemicals, each according to its own carriage conditions, with its own piping and pumping system. The cargoes they carry often present tremendous challenges and difficulties from a safety point of view, and many chemicals are also a far greater pollution threat than crude oil.

Liquid bulk chemicals are transported by dedicated chemical tankers or by chemical/oil product tankers (Figure 2). Most of the chemical transportations in the Baltic Sea are done by chemical parcel tankers. Chemical parcel tankers are versatile vessels designed to carry a wide range of liquid cargoes. Externally, they appear similar to petroleum product tankers, but typically can carry 10 to 60 separate cargo tanks to simultaneously accommodate multiple cargoes or “parcels”. They range in total cargo capacity from approximately 3,000 to 40,000 tons, although most are well under 40,000 tons. Chemical parcel tankers, like gas carriers, are governed by international construction standards. They may have cargo tanks lined with stainless steel or specialized coatings, such as epoxy, zinc silicate, or polyurethane, to ensure compatibility with a range of chemicals. The tankers have double bottoms or hulls, and maintain spaces between tank walls to prevent incompatible cargoes from coming into contact with each other.

Some cargoes will require heating, others cooling, some are so volatile that they must be kept safe under a blanket of inert nitrogen, others react violently with water and so must be handled in ultra-dry conditions. Some cargoes are highly corrosive and require tanks of the highest quality of stainless steel, while others must have tank coatings of a precise specification. Some cargoes must be kept in motion, lest they settle out, and others can only be carried in tanks that have never carried cargoes with which they are incompatible. Some cargoes can be tainted by the residue of a previous cargo even after a stainless steel tank has been meticulously cleaned and purged. Some cargoes react violently to others or to exposure to the atmosphere. Many are flammable, explosive or give off noxious vapours, so safety will always be an important consideration. Some are edible. Many of these chemical cargoes are immensely valuable, demand fantastic standards of cleanliness to maintain their product purity and must be discharged to the last drop, with none remaining on board.

Figure 2. 3,687 dwt chemical/oil products tanker Lima Chemist. Photograph courtesy of Schindler, 2005.

New products are being developed all the time by the chemical industry throughout the world and being offered for shipment. Keeping up with the new products is a special responsibility for this sector of the shipping industry that has a modern fleet of double-hulled ships ranging from 3,000 ton acid tankers to 40,000 ton chemical parcel vessels. (BIMCO, 2005; UN, 2005; Ocean Channel, 2005.)

3.2 Regulations for the carriage of chemicals by ship

Regulations governing the carriage of chemicals by ship are contained in the *International Convention for the Safety of Life at Sea* (SOLAS) and the *International Convention for the Prevention of Marine Pollution from Ships*, as modified by the Protocol of 1978 relating thereto MARPOL 73/78 (IMO, 2002). The regulations cover chemicals carried in bulk, on chemical tankers, and chemicals carried in packaged form. In this study, the relevant codes concerning liquid bulk transportations are the *International Code for the Construction of Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code) and the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code).

The IGC Code applies to gas carriers constructed on or after 1 July 1986. Gas carriers constructed before that date should comply with the requirements of the *Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (GC Code) or the *Code for Existing Ships Carrying Liquefied Gases in Bulk* (eGC Code).

Carriage of chemicals in bulk is covered by regulations in SOLAS Chapter VII – *Carriage of dangerous goods* and MARPOL Annex II – *Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk*. Both Conventions require chemical tankers built after 1 July 1986 to comply with the IBC Code, which gives international standards for the safe transport by sea in bulk of dangerous liquid chemicals, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimize the risks to the ship, its crew and to the environment, having regard to the nature of the products carried.

Basically, the ship types are related to the hazards of the products covered by the Codes. Each of the products may have one or more hazard properties, which include flammability, toxicity, corrosivity and reactivity. The IBC Code lists chemicals and their hazards and gives the ship type required to carry that product as well as the environmental hazard rating. Chemical tankers constructed before 1 July 1986 should comply with the requirements of the *Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (BCH Code) – the predecessor of the IBC Code.

Regulations concerning chemicals transported in packaged form are MARPOL Annex III – *Regulations for the Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form* and the *International Maritime Dangerous Goods* (IMDG) Code. The IMDG Code was developed as a uniform international code for the transport of dangerous goods by sea and covers such matters as packing, container traffic and stowage, with particular reference to the segregation of incompatible substances. Amendments to SOLAS chapter VII (Carriage of Dangerous Goods) adopted in May 2002 make the IMDG Code mandatory from 1 January 2004. (IMO, 2005.)

3.2.1 MARPOL categories of hazardous chemicals

MARPOL Annex II grades "noxious liquid substances carried in bulk" into four categories graded A to D, according to the hazard they present to marine resources, human health or amenities:

Category A – Noxious liquid substances that, if discharged into the sea from tank cleaning or deballasting operations, would present a major hazard to either marine resources or human health or cause serious harm to amenities or other legitimate uses of the sea and therefore justify the application of stringent anti-pollution measures. Examples are acetone cyanohydrin, carbon disulphide, cresols, naphthalene and tetraethyl lead.

Category B – Noxious liquid substances that, if discharged into the sea from tank cleaning or deballasting operations, would present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify the application of special anti-pollution measures. Examples are acrylonitrile, carbon tetrachloride, ethylene dichloride and phenol.

Category C – Noxious liquid substances that, if discharged into the sea from tank cleaning or deballasting operations, would present a minor hazard to either marine resources or human health or cause minor harm to amenities or other legitimate uses of the sea and therefore require special operational conditions. Examples are benzene (benzene and mixtures having 10% benzene or more), styrene, toluene and xylenes.

Category D – Noxious liquid substances that, if discharged into the sea from tank cleaning or deballasting operations, would present a recognizable hazard to either marine resources or human health or cause minimal harm to amenities or other legitimate uses of the sea and therefore require some attention in operational conditions. Examples are acetone, phosphoric acid and tallow.

The Annex also listed "other liquid substances" deemed to fall outside Categories A, B, C or D and therefore representing no harm when discharged into the sea from tank cleaning or ballasting operations. These substances include coconut oil, ethyl alcohol, molasses, olive oil and wine. (IMO, 2005.)

The hazardous chemicals are listed in the International Bulk Chemical Code (IBC code). Noxious liquid substances that are carried in bulk and are presently categorized as Category A, B, C or D and subject to the provisions of MARPOL Annex II are so indicated in the Pollution Category column of chapters 17 or 18 of the IBC code. Other liquid substances carried in bulk that are identified as falling outside Categories A, B, C and D and indicated as "III" in the Pollution Category column of chapters 17 or 18 of the IBC code. (IMO, 2002.)

3.2.2 Revised MARPOL Annex II

The revised Annex II *Regulations for the control of pollution by noxious liquid substances in bulk* was adopted in October 2004. It includes a new four-category categorization system for noxious and liquid substances. The revised annex will enter into force on 1 January 2007. The new categories are as follows:

Category X – Noxious Liquid Substances that, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a major hazard to either marine resources or human health and, therefore, justify the prohibition of discharge into the marine environment.

Category Y – Noxious Liquid Substances that, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation of the quality and quantity of the discharge into the marine environment.

Category Z – Noxious Liquid Substances that, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a minor hazard to either marine resources or human health and therefore justify less stringent restrictions on the quality and quantity of the discharge into the marine environment.

Other Substances – Substances that have been evaluated and found to fall outside Category X, Y or Z because they are considered to present no harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged into the sea from tank cleaning or deballasting operations. The discharge of bilge or ballast water or other residues or mixtures containing these substances are not subject to any requirements of MARPOL Annex II.

The revised Annex includes a number of other significant changes. Improvements in ship technology, such as efficient stripping techniques, have made possible significantly lower permitted discharge levels of certain products that have been incorporated into Annex II. For ships constructed on or after 1 January 2007 the maximum permitted residue in the tank and its associated piping left after discharge will be set at a maximum of 75 litres for products in categories X, Y and Z – compared with previous limits that set a maximum of 100 or 300 litres, depending on the product category.

Alongside the revision of Annex II, the marine pollution hazards of thousands of chemicals have been evaluated by the Evaluation of Hazardous Substances Working Group in the GESAMP2 Hazard Profile, which indexes the substance according to its bio-accumulation, bio-degradation, acute toxicity, chronic toxicity, long-term health effects and effects on marine wildlife and on benthic habitats.

As a result of the hazard evaluation process and the new categorization system, vegetable oils, which were previously categorized as being unrestricted, will now be required to be carried in chemical tankers. The revised Annex includes, under regulation 4 Exemptions, a provision for the Administration to exempt ships certified to carry individually identified vegetable oils, subject to certain provisions relating to the location of the cargo tanks carrying the identified vegetable oil. (IMO, 2005.)

3.3 The products

The most common chemical products transported in bulk can be classified into a number of categories (Bonn Agreement, 1999):

- heavy chemical products made in large quantities, the most common ones being sulphuric acid, phosphoric acid, nitric acid, chlorhydric acid, caustic soda and ammonia
- molasses and alcohols
- vegetable oils (soya, palm nut, sunflower...) and animal oils (lard, fish oils)
- petrochemical products: benzene, xylenes, phenol, styrene
- coal tar products: benzene, phenol, naphthalene.

The most common chemicals transported in the Baltic are ammonia, acetone, ethylene glycol, phenol, phosphoric acid, methanol, sulphuric acid, styrene monomer and caustic soda.

3.4 Chemical tanker fleet

As of January 2005, the world tanker tonnage (oil, products, oil/chemical, pure chemical and liquid gas) had a share of 41.4 per cent of the world total merchant fleet with a capacity of 368.4 million dwt. At the beginning of 2004, the average age of the chemical tanker fleet stood at 17.6 years versus 16.6 years in 2000. 20.9 per cent of the existing chemical tanker tonnage was built before 1979 (older than 25 years). In international shipbuilding, the tanker tonnage clearly dominated the world order book in 2005. The increase compared to last year's cgt figures is 76% in liquid gas tankers and 44.5% in chemical tankers. (ISL, 2005.)

According to Lloyd's Register Fairplay, there were 1,339 chemical parcel tankers in use in the world as well as 1,666 chemical/oil product tankers () and 1,886 crude oil tankers, 177 LNG (Liquefied Natural Gas) tankers and 1,025 LPG (Liquefied Petroleum Gas) tankers. The characteristics of these ship types are presented in Table 2.

Table 2. Characteristics of different tanker types (Lloyd's, 2005).

Tanker type	Number	Average GT	Average age	Average L	Average B	Average D
Chemical	1,339	3,818	17.53	85.21	13.70	5.60
Chemical/ Product	1,666	12,436	11.83	135.38	21.82	8.60
Crude Oil	1,886	75,832	11.56	251.25	42.87	15.29
LNG	177	87,505	13.43	268.28	42.00	11.15
LPG	1,025	9,440	17.04	110.88	17.71	6.59

There are 43 companies in the Baltic area (including Norway) that own or operate chemical tankers (Appendix D). These companies have about 500 chemical carriers and oil product / chemical tankers altogether (Hazardouscargo, 2005 & company websites). (See Figure 3.) Three of the largest companies operate 78% of the Baltic traffic (Rikala, 2005).

Figure 3. Maersk Nordenham – a typical chemical/oil products tanker, 16,716 dwt. Photograph courtesy of Schindler, 2005.

3.5 Marine chemical accidents

Overloading in Crystal Rubino case

In July 2000 an Italian chemical tanker was loading nonylphenol ethoxylate in the port of Hamina. As a result of overloading, two tons of the noxious chemical ended up in the sea. The sea started to foam and dead fish soon surfaced. Since this substance behaves as a sinker and dissolver, it was impossible to gather. The seagulls quickly ate the dead fish and probably ended up having no nestlings the following spring. (Helsingin Sanomat, 2003.)

The main cause of this accident was inadequacy of loading supervision supported by the open ullage hatch and the open drain tank valve (Accident Investigation Board, 2000).

The loss of Ievoli Sun

An Italian chemical product tanker, The Ievoli Sun, en route from Southampton to Genoa, began taking water in bad weather and was abandoned and later sank approximately 11 miles NW of Alderney in the English Channel in October 2000. The vessel carried a mixed cargo comprising 4000 tonnes of styrene, and 1000 tonnes each of methyl ethyl ketone and isopropyl alcohol. These chemicals are of low to moderate toxicity to aquatic life, are not persistent and have a low potential for bio-accumulation. Both of the solvents are miscible in water, whilst styrene is practically insoluble and, following release, it will rise to the sea surface and rapidly evaporate. More than 1000 tonnes of styrene are believed to have been lost to sea during the incident, resulting in an aerial plume of vapour which crossed Alderney and episodic contamination of air and water in the immediate vicinity of the wreck site. Analysis demonstrated low-level styrene contamination of crabs recovered from pots laid very close to the wreck site prior to the incident. These concentrations posed no risks to human consumers. The remainder of the styrene and the ship's main bunker fuel were recovered from the wreck on the seabed, whilst the two chemical solvents were released to the water column in a slow, controlled manner. (Marine Pollution Bulletin, 2003.)

Sinking of the chemical tanker Balu in the Bay of Biscay

On the 20th of March 2001, the maltese chemical tanker Balu, transporting 8000 tonnes of sulphuric acid, rank in a storm in the Bay of Biscay, lying down on a sea bed at a depth comprised between 4,600 and 4,800 metres, at the limit of the French and Spanish territorial waters, at about 120 nautical miles in the north of La Coruña.

Sulphuric acid is denser than water. In the absence of a sudden exothermic reaction during the sinking, the risk incurred by marine flora and fauna is a risk of mortality due to a strong acidification of their habitat, situated near the shipwreck. Leaking acid would dissolve in seawater, which has a great neutralizing capacity and represents a huge volume. So, pH (potential of hydrogen) would recover rapidly its original level in the damaged area.

At the depth concerned, sea bed populations are low in biomass by unit of surface, not much diversified and are not the subject of any exploitation. So, there would be no risk for fishing and the environmental impact, can be considered temporary and localized. (Cedre, 2001.)

Phosphoric acid tanker sank in the English Channel

A Marshall Islands registered tanker Ece carrying 10.000 tonnes of phosphoric acid sunk to a depth of 70 metres on 1 February 2006, a day after a side-on collision with a freighter General Grot-Rowecki off the North West coast of Guernsey in the English Channel. Twenty-two crew members were rescued.

The Ece had about 80 tonnes of fuel on board when it sank. A surveillance plane crew spotted what they described as a "reasonable quantity" of fuel oil bubbling from the wreck the day it sank.

According to Greenpeace, the phosphoric acid should not pose a long-term problem with a slow dilution. But the fuel oil could have a long-term and serious effect on marine life on the sea floor. The scale of the problem will depend on sea currents and how much time it takes to leak out. (BBC, 2005.)

The four accidents described above are just a few examples from the previous five years. Unfortunately, other chemical tanker accidents have happened and will happen in the future as well. In 1983, an Agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances was reached (Bonn Agreement, 1999). The contracting parties are the Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Economic Community. For the purpose of this Agreement, the North Sea area means the North Sea proper southwards of latitude 61°N, together with

a. the Skagerrak, the southern limit of which is determined east of the Skaw by latitude 57°44'43"N

b. the English Channel and its approaches eastwards of a line drawn fifty nautical miles to the west of a line joining the Scilly Isles and Ushant.

A compilation of incidents that have happened before the year 2000 in the Bonn Agreement zone, outside this zone in Europe (France, Spain, Italy) and in other parts of the world (Japan, China, Brazil, USA) is presented in Table 3. The behaviour of the product is presented inside the brackets after the name of the product.

Table 3. Chemical incidents at sea (Bonn Agreement, 1999).

Name of ship	Year	Chemical products	Country	Maritime zone
DISSOLVERS IN BULK				
ANNA BROERE	1988	Acrylonitrile (DE) Dodecylbenzene (F)	Holland	North Sea
ALESSANDRO PRIMO	1991	Acrylonitrile (DE) Dichloroethane (SD)	Italy	Mediterranean
PANAM PERLA	1998	Sulphuric acid (D)	–	Atlantic
BAHAMAS	1998	Sulphuric acid (D)	Brazil	Atlantic
FLOATERS IN BULK				
LINDENBANK	1975	Coconut oil (F)	Hawaii	Pacific
KIMYA	1991	Sunflower oil (F)	Great Britain	North Sea
GRAPE ONE	1993	Xylenes (FE)	Great Britain	Channel
CHUNG MU	1995	Styrene (FE)	China	China Sea
ALLEGRA	1997	Palm nut oil (F)	France	Channel
SINKERS IN BULK				
NORAFRAKT	1992	Lead sulphur (S)	Holland	North Sea
FENES	1996	Wheat (S)	France	Mediterranean
GASES OR EVAPORATORS IN BULK				
YUYO MARU	1974	Propane (G) Butane Naphtha	Japan	Tokyo Bay
ASCANIA	1999	Vinyl acetate (ED)	Great Britain	North Sea

The statistical study made by the U.S. Coast Guard (HSSR, 1999) in the United States over 5 years (1992–1996) lists 423 spills of hazardous substances from ships or port installations. The nine most frequently spilled products are presented in Table 4.

Table 4. Marine chemical spills in USA, 1992–1995 (HSSR, 1999).

Product	Number of spills	Behaviour classification
Sulphuric acid	86	Dissolver
Toluene	42	Floater/Evaporator
Caustic soda	35	Dissolver
Benzene	23	Evaporator
Styrene	20	Floater/Evaporator
Acrylonitrile	18	Dissolver/Evaporator
Xylenes	18	Floater/Evaporator
Vinyl acetate	17	Floater/Dissolver
Phosphoric acid	12	Dissolver

HELCOM annually collects data on ship accidents in the Baltic Sea. According to the statistics, pollution from chemical tanker accidents is still rare in the Baltic. From 1989 to 2003 there were only three cases where chemicals were leaked into the sea (Table 5 and Figure 4).

Table 5. Baltic Sea ship accidents where chemicals were leaked into the sea 1989–2003 (HELCOM, 2005).

Date	Ship	Ship size (dwt)	Latitude/ Longitude	Incident	Leakage
Feb 1996	Tom Lis, Portugal	2,541	57,833/ 12,017	Leakage	Orthoxylen 0.5 m^3
May 1999	Omsky-1, Russia	3,000	59,933/ 30,250	Collision	Oil+chem. 10 m^3
June 1999	Volgo-Don, Russia	5,000	59,933/ 30,500	Collision	Chemicals 12 m^3

Figure 4. Chemical accidents in the Baltic Sea 1989–2003 (HELCOM, 2005).

The Helsinki Commission has published an extensive manual on how to respond to accidents at sea involving spills of hazardous substances and loss of packaged dangerous goods (HELCOM, 2002). The HELCOM Response Group updates and reviews the Response Manuals – Volume 1 (Oil) and Volume 2 (Chemicals) continuously. The steadily growing maritime traffic also means that ship accidents causing marine pollution have become more probable. Full case histories of the accidents can be found in the Response Manual (HELCOM, 2002).

In Figure 5, this tanker, laden with 63,000 tonnes of gasoil, ran aground in the Kattegat in September 2004. The casualty was refloated following the transfer of 8,000 tonnes of cargo. (International Salvage Union, 2005.)

Figure 5. Fotini Lady during salvage operation. Photograph courtesy of the International Salvage Union.

4. Previous chemical transportation studies

4.1 Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area

HELCOM has studied Baltic chemical transportations in *Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area* (HELCOM, 1990). This report is the most extensive report so far on chemical transportations in the Baltic Sea area. The statistics from the area were used to identify transportation patterns in the Baltic and the related risks of outflow and potential hazards to the marine environment.

According to the statistics from 1987, 5.8 million tons of liquid and 2.9 million tons of gaseous chemicals in nearly 4,000 shipments were transported in the Baltic Sea. They were percentually divided into MARPOL groups as presented in Table 6. The total number of different chemicals transported was 145, of which 9 were gases. These are divided into MARPOL categories in Table 6.

Table 6. 1987 shipments divided into categories.

Category of chemical	Percentage of all transportation tons	Number of chemicals in category
A	2%	12
B	8%	29
C	25%	37
D	20%	44
Appendix III	12%	14
Gases	33%	9

The average size of the liquid chemical parcel load was about 2,000 tons and the average of the gas load was about 2,900 tons.

4.2 Study of the transportation of packaged dangerous goods by sea in the Baltic Sea area and related environmental hazards

HELCOM has also published a *Study of the transportation of packaged dangerous goods by sea in the Baltic Sea area and related environmental hazards* (HELCOM, 1993). This study was performed under the auspices of the Combatting Committee of the transportation of packaged dangerous goods in the Baltic Sea area. The study is based on information collected from all ports in the area of loading and unloading of packaged dangerous goods during October and November 1990. Although this limited time period may be too short for producing statistically reliable data, the large amount of information thus collected gives very useful information about the transportation of packaged dangerous goods, previously not available.

4.3 Transport of Hazardous Substances 2002

The Finnish Ministry of Transport and Communications compiles a report on the transport of dangerous goods by road, rail, sea and air every five years. The newest report, *Transport of Hazardous Substances 2002* (LVM, 2004), was published in 2004 and it contains data from the year 2002. The sea transportation statistics are from the Finnish Maritime Administration and contain the total amount of bulk and parcelled goods and the transport distribution between different ports.

In 2002, 4.9 million tons of chemicals were transported in bulk by sea. The amount of gas cargo was 377 thousand tons. Compared to the 1997 numbers, chemical bulk transport had increased by 56% (3.1 million tons in 1997) and gas transport had increased by 11% (339 thousand tons in 1997). Transportation of dangerous cargo in bulk (gases, chemicals, oil, solid bulk) covers 98.1% of all dangerous cargo transport by sea.

GASES: The proportion of gases of all dangerous bulk is only 1%. Most of the gases, about 86%, are flammable. About 13% are poisonous. The proportion of non-poisonous, non-flammable gases was less than 1%. The gases transported were mainly propane, vinyl chloride, ammonia, ethene and butadiene.

CHEMICALS: The proportion of chemicals of all dangerous bulk in 2002 was 13%. Liquid chemicals were percentually divided into MARPOL groups as follows:

A	1%
B	8%
C	21%
D	59%
Appendix III	11%.

The most common chemicals handled in Finnish ports in 2002 were as presented in Table 7.

Table 7. The most common chemicals handled in Finnish ports in 2002 (LVM, 2004).

Chemical	Volume (tons)	MARPOL class
Ethylene glycol	1,195,700	D
Methanol	669,424	D
Caustic soda (lye)	511,945	D
Phenol	349,898	C
Acetone	318,937	Appendix III
Phosphoric acid	257,824	D
Sulphuric acid	306,369	C
Styrene monomer	209,997	B
Xylenes	175,393	C
Methyl tert-butyl ether	160,545	D

4.4 Combating of Marine Chemical Spills and Requirements for the Combating Ship

The VTT study on *Combatting of Marine Chemical Spills and Requirements for the Combatting Ship* (VTT, 1995) covers the sea transport statistics of hazardous substances carried in bulk in Finnish ports during 1994. The statistics were updated by sending a questionnaire to Finnish ports. Eighty-three different chemicals were found and divided into MARPOL classes A–D and non-pollutants (Appendix III). In addition, there were 4 different gases. Also, the chemicals were divided according to their chemical and physical properties and their behaviour in seawater. Grading complies with the 12 property groups of chemicals as shown in (Bonn Agreement, 2000). A list of the chemicals is in Appendix E.

According to these statistics, four million tons of liquid chemicals and 131,000 tons of gases were transported through Finnish ports in 1994. The updated statistics showed that the transportations in question had strongly increased when compared with the previous corresponding statistics from the year 1987. Both the amount and types of hazardous cargo transported had increased. Liquid chemicals were percentually divided into MARPOL groups as follows:

A	1%
B	13%
C	28%
D	27%
Appendix III	31%.

4.5 Combating preparedness in 2005 and 2010

The Finnish Environment Institute has estimated the required combating preparedness in Finland and its neighbouring areas in 2005 and 2010 (Jolma, 1999). In 1997, Finnish marine chemical transportations totalled already 5.9 million tons. Transportations had doubled in 10 years compared to the statistics used in (HELCOM, 1990). Chemicals still constituted only 7% of all marine transportations in Finland in 1997 (82.7 million tons).

5. Transportation statistics

In order to gather chemical transportation statistics from Baltic ports an inquiry was sent by email to 55 ports. The ports were selected on the basis of national statistics indicating that some chemicals might be handled in these ports. The inquiry and the port list are in Appendix F. Thirty ports filled in and returned the questionnaire, and some answers were more precise than others. The answers to the questionnaire are studied in this chapter, as well as all the other relevant information about the ports. Those ports that answered that they did not handle liquid chemicals are not mentioned here. HELCOM as well as national maritime administrations helped us to get statistics from some ports. During the study it was discovered that a few more ports handle chemicals too, so the total amount of the ports described here is 46 (Figure 6).

Chemical transportations seem to be a very sensitive area to seek information about, since it is quite common that a port imports or exports chemicals to or from only one chemical industry plant, and information may not be available because of competition factors.

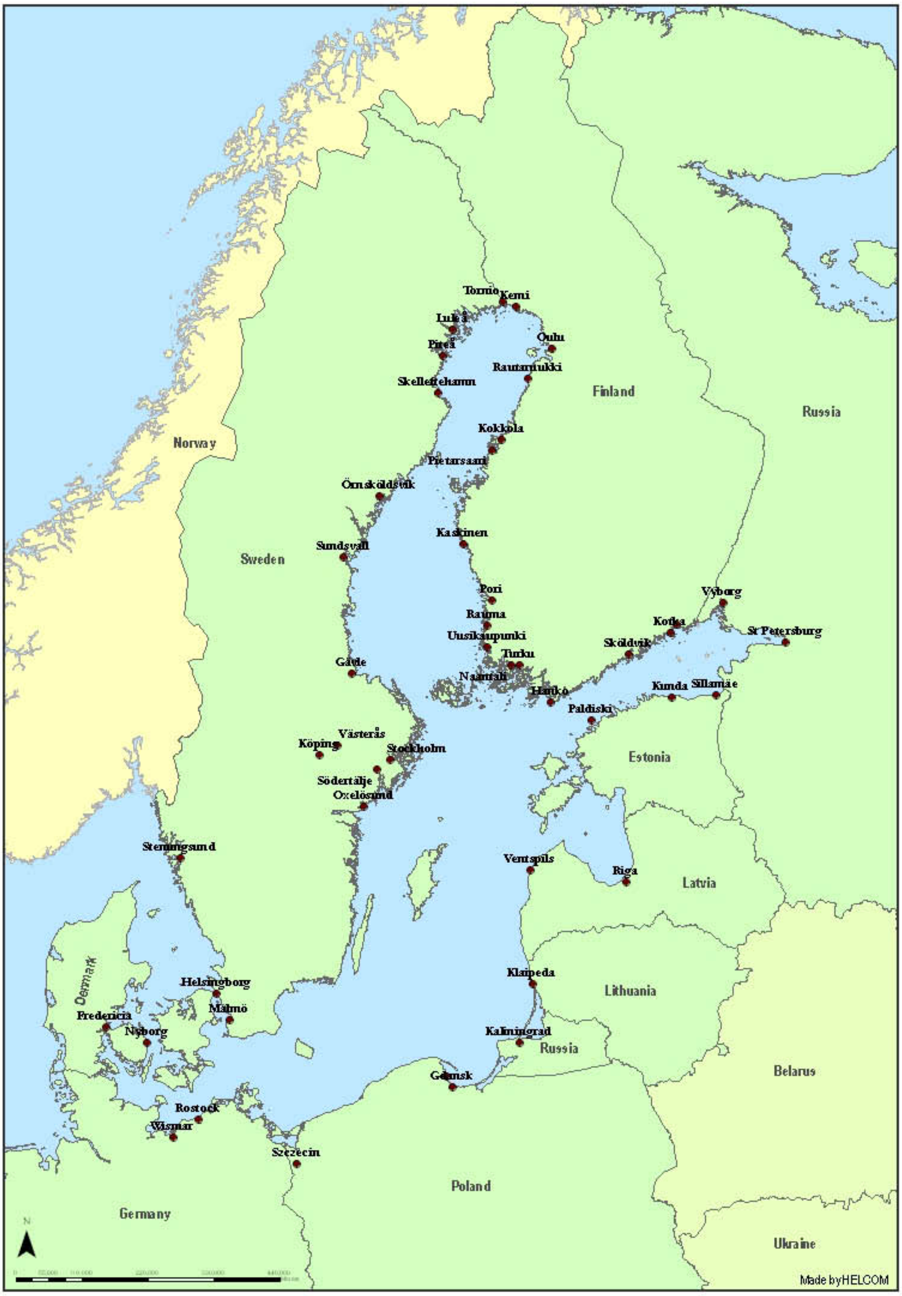

Figure 6. Liquid chemical ports in the Baltic Sea area.

5.1 Finland

According to the statistics from 1994 (VTT, 1995), altogether 3.8 million tons of liquefied chemicals and 0.4 million tons of gases were transported to or from Finnish harbours ten years ago. In 2004 the amount of all chemical transportations in Finnish harbours was already 5.6 million tons. (See Figure 7.) In 1994, there were 14 ports that handled chemicals. Ten years later, the number of harbours had grown to 22.

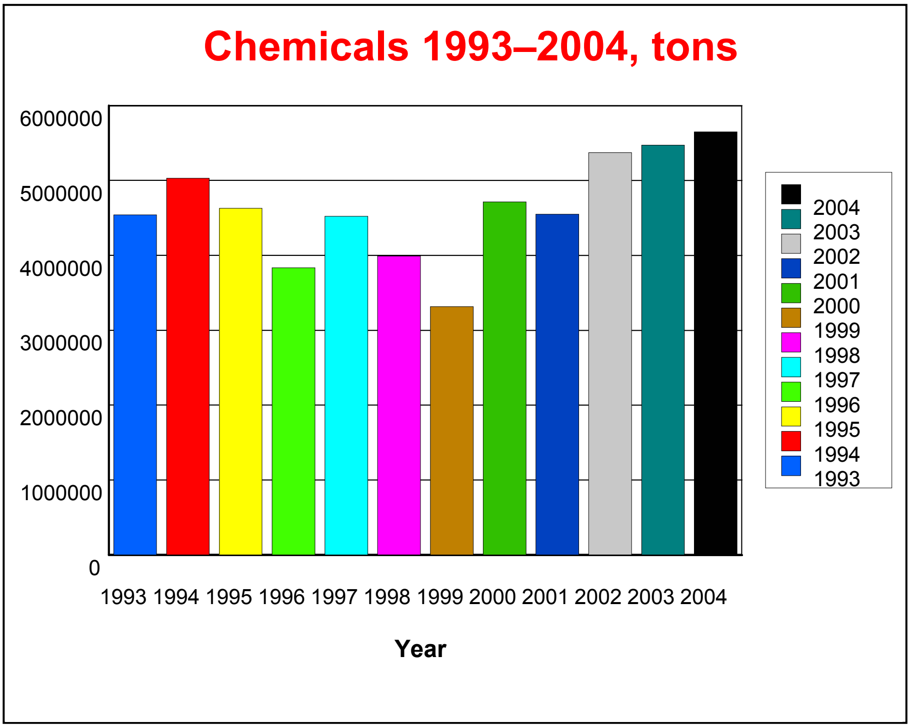

Figure 7. Chemicals handled in Finnish ports 1993–2004 (FMA, 2005c).

In 2004, there were 22 ports that handled chemicals (FMA, 2005b). Not all of these necessarily handled liquid chemicals. In Table 8, the total volume of all chemicals imported to and exported from Finnish ports is presented. In Finnish shipping statistics, fertilizers are reported separately from chemicals, so they are not included in these numbers. On the other hand, liquid and solid chemicals are not separated, so these numbers include both. The inquiry was sent to the 18 largest chemical ports, marked in bold colour in the table.

Table 8. All chemicals handled in Finnish ports in 2004 (FMA, 2005b).

Port	Import (tons)	Export (tons)	**Total (tons)**
Hamina	292,599	838,995	**1,131,594**
Kotka	114,389	886,265	**1,000,654**
Loviisa	3,560		**3**,560
Sköldvik	235,456	308,342	**543,798**
Helsinki	150,123	221,026	**371,149**
Inkoo	12,176		**12,176**
Hanko	19,281	48,553	**67,834**
Turku	40,182	26,472	**66,654**
Naantali	52,001	5,987	**57,988**
Uusikaupunki	97,250	162,409	**259,659**
Rauma	116,294	91,234	**207,528**
Eurajoki	1,910		1,910
Pori	190,173	450,576	**640,749**
Kaskinen	51,158		**51,158**
Vaasa	6,797		6,797
Pietarsaari	122,083		**122,083**
Kokkola	108,137	229,470	**337,607**
Rahja	3,700		3,700
Rautaruukki	5,822	48,150	**53,972**
Oulu	405,274	155,110	**560,384**
Kemi	95,839	29	**95,868**
Tornio	47,556		**47,556**
TOTAL	**2,171,760**	**3,472,618**	**5,644,378**

Note! These numbers include all chemicals, also other than liquified, imported and exported to and from Finnish ports in 2004.

Foreign trade is vital for Finland, and sea transportation forms 4/5 of it. The most important sectors, calculated in tons, in Finnish sea export are the paper and timber industry, chemical industry and metal industry. In sea import the most popular products are crude oil, coal, ore, other minerals plus products from the chemical and metal industry.

International trade in Finland is expected to double from 2000 to 2020. Even without crude oil, sea transports at the point of contact between the Baltic Sea and the Gulf of Finland are expected to triple. The growth in sea transportation follows the average growth of such strong growth industries as the metal and chemical industries and commodities.

Russian industrial chemicals make up a great part of the transito traffic in the ports of Hamina and Kotka these days. Some 1.5–2 million tons of chemicals are carried to the west through these ports. The substances include for example xylenes, styrene, glycol, paraffin, phenol, acetone and methanol. The tankers of a Finnish shipping company, Crystal Pool Ltd, carry 35% of Russian industrial chemicals around the Baltic Sea. Another big name in the area is Norwegian Utkilen Rederi AS. In the future, the chemical transito traffic may be rerouted through Russian and Estonian ports, as has happened with oil transportations as well. (Kauppalehti, 2005.)

Last year, the growth in chemical export to Russia was 12%. Russia is the most important buyer of drugs from Finland (more than a third of the entire export of drugs). Chemical export to Sweden grew by 8% in 2004. Import from Sweden is greater than export. (Finnish Customs, 2005.)

The following figures present the breakdown of chemical traffic by foreign (Figure 8) and Finnish ports (Figure 9). Rotterdam has been the main trading partner during the whole decade. The ports of Kotka and Hamina are the greatest chemical handlers in Finland.

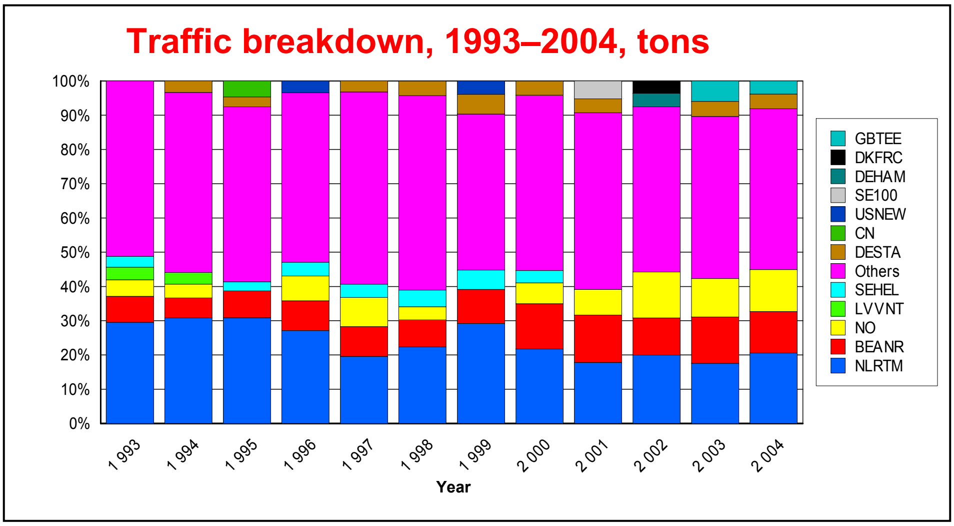

Figure 8. Breakdown of chemical traffic by foreign ports (FMA, 2005c).

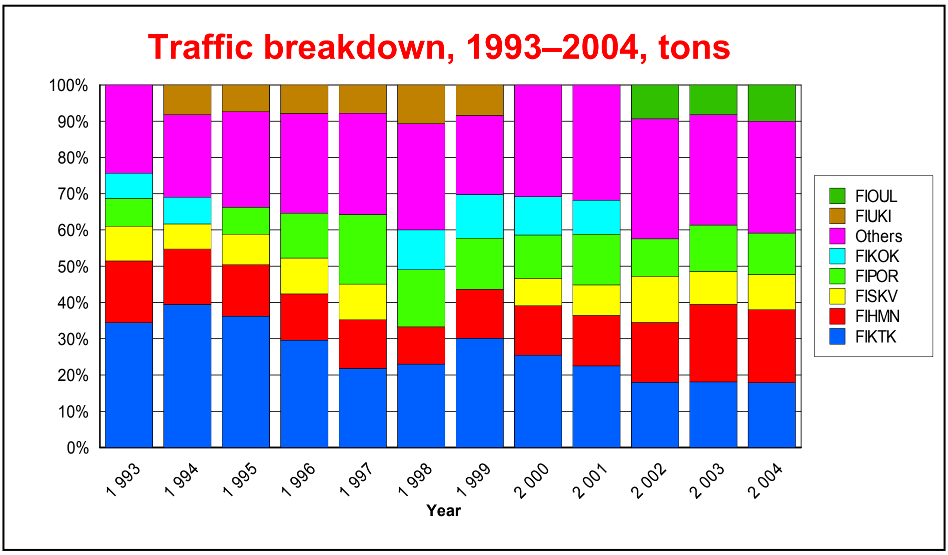

Figure 9. Breakdown of chemical traffic by Finnish ports (FMA, 2005c).

5.1.1 Hamina

There are altogether 17 chemical companies located in the port of Hamina. A great deal of the chemical transportations in Hamina comes from Russia, and the most important destinations are Rotterdam, Antwerp, Teesport, Hamburg and Gdynia. The import and export structure in Hamina is presented in Table 9. A total of 325 tankers visited Hamina, and 215 of these were chemical carriers.

Table 9. Chemical transportations in Hamina, 2004.

IMPORT	**ton**	**class**
Butadiene	53,926	2.1. gases
Butyl acrylate	12,233	3 flammable liquids
Phenol	1,038	6.1. toxic
Caustic soda	78,547	8 corrosive substances
Methyl ethyl ketone	501	3 flammable liquids
Sulphuric acid	39,492	8 corrosive substances
Styrene monomer	3,380	3 flammable liquids
Vinyl acetate monomer	1,457	3 flammable liquids
TOTAL	**190,574**	
EXPORT	ton	**class**
Butane	741	2.1.gases
Isoprene	8,271	3 flammable liquids
Methanol	762,012	3 flammable liquids
Methyl tert-butyl ether	83,104	3 flammable liquids
Nonylphenol ethoxylated	48,830	8 corrosive substances
Propane	2,839	2.1.gases
Propylene	5,897	2.1.gases
Styrene monomer	9,602	3 flammable liquids
Vinyl acetate monomer	457	3 flammable liquids
TOTAL	**921,753**	
TOTAL ALL	**1,112,327**	

5.1.2 Kotka

A great many of the chemical transportations in Kotka consist of Russian transit cargo. The port of Kotka did not provide us with accurate statistics, but according to national statistics (FMA, 2005b), the import of chemical products on tankers totalled 114,388 tons, the main ports of departure being Antwerp, Rotterdam and Wilhelmshaven. The export of liquid chemicals was 877,438 tons, mainly to Rotterdam, Antwerp, Teesport, Hamburg, Gdynia, Wismar, Norrköping and also to China.

Importer of industrial chemicals and raw materials Bang & Bonsomer will move its central warehouse from Helsinki to Kotka. The company will have about 5,000 items in stock. (Kymen Sanomat, 2004.)

5.1.3 Sköldvik

Sköldvik is mainly known as an oil port, but some chemicals are also handled there. Twenty-nine vessels imported chemicals from Rotterdam, Stade, Stenugnsund and the USA, while chemicals were exported on 67 vessels to Rotterdam, Antwerp, Billingham and Teesside (Table 10).

Table 10. Chemical transportations in Sköldvik, 2004.

IMPORT	**ton**	**EXPORT**	**ton**
Benzene	7,090	Acetone	88,469
Dioctyl Phthalate (DOP)	2,537	Phenol	117,196
Monopropylene Glycol (MPG)	7,093	**TOTAL**	**205,665**
Styrene Monomer	26,418		
Treated SCN (Thiocyanate)	2,639	**TOTAL ALL**	**251,443**
TOTAL	**45,778**		

There are plans for building a biodiesel plant in Sköldvik, and it will increase the transportation of vegetable oils. Even though vegetable oil does not sound very harmful, in case of a leak it makes birds as dirty as any other oil.

5.1.4 Hanko

Chemical transport in Hanko seems to consist mainly of IMDG cargo. In 2004 there were only three chemical tanker visits in the port of Hanko. The vessels came from Hamina, Rotterdam and Gothenburg and unloaded altogether 4,200 tons of butylacrylate (UN 2348), vinyl-acetate monomer (UN 1301) and 2-ethylhexanol (UN 1987). The import volume has decreased, as before there were 6–8 vessels yearly. The fourth substance that used to be imported was styrene monomer (UN 2055).

5.1.5 Turku

Fifteen chemical tankers visited Turku last year. They imported versene 80 (9,211 tons), versene 100 (3,684 tons) and propylene glycol (3,396 tons), and exported other chemicals up to 3,297 tons. The ports of destination or origin were Sköldvik, Teesport, Södertälje, Stade, Gdynia and Paldiski.

5.1.6 Naantali

The port of Naantali did not provide us with accurate statistics, but according to national statistics (FMA, 2005b) the import of chemical products on tankers totalled 46,229 tons, the main ports of departure being Amsterdam, Rotterdam and New Orleans. The export of liquid chemicals was 5,987 tons to Harwich.

5.1.7 Uusikaupunki

The port of Uusikaupunki did not provide us with accurate statistics, but according to national statistics (FMA, 2005b) the import of chemical products on tankers totalled 80,741 tons, the main ports of departure being Stade, Rotterdam, Ventspils, Fredericia and Hull. The export of liquid chemicals was 162,409 tons, mainly to Helsingborg, the Netherlands, Eastham and Fredericia. Export consists of phosphoric acid and fluoro-silicon acid.

5.1.8 Rauma

In the port of Rauma, liquid chemical import totalled 112,155 tons and export 93,860 tons, transported on 74 tankers. The chemicals usually arrived from Rotterdam, Södertälje, Oulu, Sandarne or Pori. The most important destinations were Kotka, Gävle, Uusikaupunki, Immingham and Sköldvik. The most common substances handled and their amounts are presented in Table 11.

Table 11. Chemicals handled in Rauma.

Product	Volume	UN class	IMDG class
Tall oil pitch	65,673 t		
Caustic soda	54,946 t	un 1824	imdg 8.0
Styrene monomer	39,719 t	un 2055	imdg 3.3
Tall oil fatty acid	8,476 t		
Crude tall oil	6,083 t		
Acetic acid	5,195 t	un 2789	imdg 8.0
Monopropylene glycol	4,698 t		imdg 3.3
Epichlorohydrine	4,402 t	un 2023	imdg 6.1
Xylenes	4,026 t	un 1307	imdg 3.2

5.1.9 Pori

Fifty-four chemical carriers visited Pori last year, importing 173,361 tons of caustic soda from Rotterdam and exporting 133,975 tons of sulphuric acid to Imminghamm and Gävle in addition to sodium chlorate to Husum/Iggesund.

5.1.10 Kaskinen

There is no chemical export from Kaskinen, but altogether 51,158 tons of caustic soda was imported, mainly from Norway.

There is a new bulk quay under construction for caustic soda, hydrogen peroxide, heavy fuel oil and other liquid bulk for the needs of the forest industry (Vasabladet, 2005).

5.1.11 Pietarsaari

The port of Pietarsaari is also used for forest industry needs. Export articles include cellulose, tall oil and zinc. Caustic soda and pulpwood are the main import articles.

5.1.12 Kokkola

	Import	Export	Total
Sulphuric acid	3,308.00	6,507.24	9,815.24
Phosphoric acid		166,077.95	166,077.95
Caustic soda	77,218.95		77,218.95
Ammonia	8,000.17		8,000.17
TOTAL	**88,527.11**	**172,585.19**	**261,112.31**

5.1.13 Rautaruukki

Export: benzene, 10,131 tons on three vessels to Rotterdam, and tar, 36,167 tons on nine vessels to Aviles, Zelzate, Amsterdam and Nyborg.

5.1.14 Oulu

Import in liquid chemical bulk to Oulu was 58,974 tons and export 91,076 tons. The number of chemical tankers calling at the Port of Oulu in 2004 was 14. Imported substances included al.hydroxide, styrene monomer and tall oil. Exported substances included formic acid and tall oil. Important ports of departure were Elnesvågen in Norway, Szczecin in Poland and Nyborg in Denmark; the main destination was Rotterdam in the Netherlands.

5.1.15 Kemi

Altogether 79,590 tons of caustic soda was imported to Kemi from Rotterdam.

5.1.16 Tornio

About 80,000 tons of propane gas are handled in Tornio every year.

5.2 Sweden

The Swedish Baltic Sea coastline extends all the way from the northernmost part of the Bothnian Bay to the Skagerrak, a distance of more than 1,500 kilometres. In 2003, 11.5% of Swedish export and 10.7% of import consisted of chemicals (Federal Statistical Office, 2005). In 2004, 3,262,000 tons of chemicals, including 353,000 tons of paper mass, etc., were imported by ships to Sweden. Exports totalled 3,474,000 tons, including 2,241,000 tons of paper. The transport of actual chemicals was about 4.1 million tons. (SIKA, 2004.)

Important chemical ports are Helsingborg, Skelleftehamn, Stenungsund and Gävle. Caustic soda is transported widely from all the paper factories in Sweden. Wibax AB has its head office in Piteå. The company deals in imports, sales, storage and distribution, primarily of liquid chemical products.

As in the previous chapter concerning Finland, those ports handling a significant amount of liquid or gaseous chemicals are presented separately below. In addition to these, there are a few other smaller chemical ports in Sweden. One of these is Kalmar, where handling of chemicals in liquid bulk totalled 12,452 tons (import only). The most common chemicals were butyl acetate, mosstanol, xylenes, aromatic solvent, N-paraffin and ethanol. The number of vessels in 2004 was 13. The most important destinations and ports of departure were the Antwerp/Rotterdam area and Kotka. (Molitor, 2005.)

Another, perhaps significant, chemical port although only mentioned briefly here is Gothenburg. It remained unclear whether there really are chemical transportations to or from Gothenburg. In a typical year, the port of Gothenburg is visited by 11,000 vessels. Most of these calls are made by short-sea ferries, the rest being mainly tankers, container vessels and cargo-only roll on/roll off ferries. With 2,400 tanker calls per year and three refineries, the port of Gothenburg is one of Scandinavia's largest oil terminals. There is also extensive storage business for oil products and chemicals. Apart from statistics on crude oil (9 million tons) and petroleum products (9 million tons as well), liquid bulk chemicals have not been mentioned separately in the port's annual report. (Port of Gothenburg, 2005.)

One substance, that has only recently become an important factor in Swedish chemical markets, is ethanol. Some 200,000–300,000 tons of ethanol is imported yearly, mainly from Rotterdam, to several different ports in Sweden. Ethanol is used for refining biodiesel. (Rikala, 2005.)

5.2.1 Luleå

Mainly different kinds of oil products are imported to Luleå, but some chemicals are exported from there too. In 2004, 25,000 tons of coal tar were transported from Luleå to other places within Sweden and 7,000 tons of benzene were exported within the Baltic Sea. In addition to this, 6,000 tons of ethanol were imported from Brazil. (Molitor, 2005.)

5.2.2 Stenungsund

Stenungsund is an important chemical port, and both liquid and gaseous chemicals are transported. The chemicals imported to Stenungsund include ethene, ammonia, butanol, ethylhexanol and dioctylphtalate. The amount of chemicals handled in 2004 was over 200,000 tons. In addition to this, over ### million tons of virgin naphtha and steam cracked naphtha were handled. (Molitor, 2005.)

5.2.3 Örnsköldsvik

Wibax Ab has a terminal with a capacity of 38,000 m^3 in Örnsköldsvik. There is both import and export in Örnsköldsvik, and chemicals handled include ethanol, acetic acid and ethyl acetate. The total amount in 2004 was about 135,000 tons. (Molitor, 2005.)

5.2.4 Sundsvall

About 8,000 tons of ethanol and 50,000 tons of propane gas were imported on 15 vessels to Sundsvall in 2004 (Molitor, 2005).

5.2.5 Gävle

Caustic soda is the main article in Gävle's chemical transportations. Altogether 123,000 tons of it was imported from Rotterdam and Stade in 2004. The second most common substance is sulphuric acid, of which altogether 50,000 tons were imported from Finland (Pori) as well as from other Swedish ports. Nearly 40,000 tons of vanicell (lignosulphonate) were imported from Norge. A small amount of turpentine was exported to France. (Molitor, 2005.)

5.2.6 Stockholm

The port of Stockholm handled some 70,000 tons of sulphate pitch imported mainly from outside Sweden. Also 48,000 tons of fat in some form were imported. (Molitor, 2005.)

5.2.7 Mälarhamnar

Mälarhamnar AB is located by Lake Mälaren, close to the industrial centre in central Sweden. Mälarhamnar has ports in Köping and Västerås (Figure 10).

Figure 10. The location of inland ports of Köping and Västerås (www.malarhamnar.se).

Since quite a lot of chemicals, especially ammonia, are imported to these inland ports from foreign countries, it is important to mention them here. In 2004, nearly 170,000 tons of ammonia was transported along the Baltic Sea to these ports located behind Stockholm. Other articles handled in smaller quantities, mainly imported, were phosporic acid, nitric acid, vanicell (lignosulphonate), ethanol and sulphate pitch oil. (Molitor, 2005.)

5.2.8 Malmö

Not all of the statistics are publically available. However, in 2004 chemicals (imported) amounted to 52,000 tons. This included for example the following substances: ethanol, xylenes, ethyl acetate, toluene, acetone, isopropanol, methyl-ethyl-ketone and methanol. Almost half of the total amount consisted of methanol. (Molitor, 2005.)

5.2.9 Södertälje

In addition to petroleum products also some chemicals (77,000 tons) were handled in Södertälje in 2004. The chemicals were pitch tall oil and carbon dioxide, as well as some others.

5.2.10 Piteå

Wibax Ab has a small terminal in Piteå. Two vessels imported 31,000 tons of propane and two vessels a small amount of ethanol. (Molitor, 2005.)

5.2.11 Skelleftehamn

Total liquid chemical transport in 2004 was 579,299 tons, including 74,706 tons of imported caustic soda solution (UN 1824) and 504,593 tons of exported sulphuric acid (UN 1830). The number of vessels in 2004 was 78. Caustic soda came mainly from Gdansk and sulphuric acid went mainly to Immingham and Rotterdam but also to the USA. Wibax Ab has a terminal with a capacity of 39,000 m^3 in Skelleftehamn. (Molitor, 2005.)

5.2.12 Oxelösund

There were 32,000 tons of chemicals handled in Oxelösund in 2004. This consisted of about 12,000 tons of caustic soda (50%) from Antwerp, delivered in 3 ships, and of about 20,000 tons of sulphuric acid (95%) in 4 ships. Two ships were loaded in Rönnskärsverken (Skellefteå, Sweden). One ship arrived from Pori, Finland and one from Sarpsborg. Wibax Ab has a terminal with a capacity of 11,000 m^3 in Oxelösund. (Molitor, 2005.)

5.2.13 Helsingborg

Helsingborg is an important chemical port in Sweden. Sulphur (imported 130,000 tons) and sulphuric acid (exported 207,000 tons) were the most common chemicals handled in Helsingborg in 2004. Other chemicals (500,000 tons altogether, though not all liquid) included for example caustic soda, aluminium chloride, phosphoric acid, ferric chloride, calcium chloride, potassium sulphate, sodium chloride and silicon acid. (Molitor, 2005.)

5.3 Denmark

Denmark is situated at the entrance to the Baltic Sea, with Kattegat and the Belt Sea forming the main parts of the inner Danish marine waters. These areas are very important for fishery and recreation activities, and the shipping routes through these areas are extremely important for all the Baltic countries. According to the statistics of Danish ports, the handling of chemicals is marginal in Denmark. Nonetheless, 13.2% of Danish export and 11.0% of import consists of chemicals. (Danske Havne, 2005.)

According to national statistics (Danmarks Statistik, 2005), chemicals were handled as follows in 2004: all chemicals 539,000 tons, unloaded chemicals 419,000 tons and loaded chemicals 120,000 tons. This includes all chemicals, not just liquid bulk.

5.3.1 Fredericia

Fredericia has a big oil terminal, and it is possible, if not probable, that also some liquid chemicals are handled there. At least acid is exported from Finland to Fredericia. (Rikala, 2005.)

5.3.2 Nyborg

Coal tar imported from China, Raahe and Luleå (Rikala, 2005). Also some chemicals are exported at least to Finland.

5.4 Germany

Unfortunately the information received from Germany was incomplete and the amounts of the chemicals handled in ports remained unclear. It is also unclear whether liquid bulk chemicals are handled also in other Baltic ports in Germany than these two, Rostock and Wismar.

5.4.1 Rostock

Methanol is imported.

5.4.2 Wismar

Methanol and styrene monomer are imported. Also some chemicals are exported at least to Finland.

5.5 Poland

Poland is one of the most populous and largest countries in the Baltic Sea region, particularly in its drainage basin. Half of the inhabitants in the Baltic Sea region live in Poland. The 528 km shoreline of the Baltic forms about 15% of the country's border. The coastal zone is inhabited by about 10% of the country's population and is home to a variety of economic activities linked to shipbuilding, fisheries and marine transport, chemical industry and tourism. In 2002, 10% of Polish export and 18% of import consisted of chemicals, plastics and rubber products. (Federal Statistical Office, 2005.)

5.5.1 Gdynia

Chemicals handled in liquid bulk: import 95,565 tons + export 49,825 tons = total 143,390 tons. The most common chemicals handled in Gdynia are listed in Table 12. The number of chemical tankers that visited Gdynia in 2004 was 100. Most of the vessels came from the Netherlands, Belgium, Finland and Estonia. (Zaplatka, 2005.)

Table 12. The ten most common chemicals handled in Gdynia and their volume in tons.

Substance	Tons	Number of ships
Methyl-butyl ether (MTBE)	29,619	19
Paraxylen	23,538	18
Ethylene glycol (MEG)	6,361	4
Phosphoric acid	14,791	9
Diethylohexyl (2EH)	21,686	14
Dioctyle phthalate (DOP)	15,827	10
Butane (n-butanol)	8,196	5
Toluene	6,067	4
Mosstanol	10,134	6
Benzol/benzene	1,553	1

5.5.2 Gdansk

There are terminals for sulphur, salt, soda, chemicals and fertilizers. Fertilizers are mainly dry cargo but also urea UAN. These and chemicals (sulphur and hydrochloric acid) are mainly handled by Chemiki Ltd. (Port of Gdansk, 2005.)

In terms of bulk cargo there are plans for the development of specialist terminals in compliance with the changes that occurred in Poland's foreign trade and the trends resulting from globalization on the European market. Expansion investment projects include terminals situated in the northern port, such as grain and fodder, liquid chemicals and ore terminals. (Port of Gdansk, 2005.)

The number of chemical tankers visited in Gdansk in 2004 was 112. The destinations were mainly Baltic and North Sea ports, the United Kingdom and occasionally the USA. The most common chemicals handled in Gdansk are listed in Table 13. (Zaplatka, 2005.)

Table 13. The most common chemicals handled in liquid bulk (only export) in Gdansk.

Substance	Tons	Number of ships
Sulphuric acid (C)	63,742 loaded	6
Hydrochloric acid (D)	15,464 loaded	11
Caustic soda (D)	81,172 loaded	31
Urea ammonium nitrate solution (D)	318,045 loaded	15
Carbon dioxide liquefied	19,511 unloaded	23

5.5.3 Szczecin and Swinoujscie

Chemicals handled in liquid bulk consisted mainly of methanol: import 55,489 tons + export 900 tons = total 56,389 tons. It was carried in 16 tankers. Most of the vessels came from Aarhus, Stenungsund, Tjeldbergodden, Aalborg, Muuga, Kambo and Malmö. Export was to Stenungsund only. (Zaplatka, 2005.)

There were no transportations from Swinoujscie (Zaplatka, 2005).

5.6 Lithuania

In Lithuania, the Baltic Sea has great industrial value (Klaipeda State Seaport with transportation infrastructure, Butinge Oil Terminal and fishery) as well as environmental and cultural value. The Curonian Spit National Park was established to preserve the landscape and ethnocultural heritage of the Lithuanian coastal area along with the sand dunes, which are unique in Europe. In 2000 this national park was inscribed as a cultural landscape in the World Heritage List. In Lithuania, chemicals are handled only in Klaipeda. The Butinge Oil Terminal announced that they handle only oil. Lithuanian chemical industry products are presented in Table 14. (Statistics Lithuania, 2005.)

5.6.1 Klaipeda

Exported in 2004
Carbonate and ammonium saltpetre solution compound 933,251 t

Imported in 2004
Orimulsion 62,524 t
Molasses 46,000 t

328 chemical and oil tankers have departed from the Port of Klaipeda.

The most common ports of departure are Hamburg, Montreal, Nordkoping, La Polis, Arhus, Amsterdam, Ventspils, New York, Portland, Oslo, Gavle, Karlshamn, Gothenburg and Riga. The most common destinations are Stockholm, Copenhagen, Rotterdam, Gdansk, Bilbao, Gulfhaven, Amsterdam and Hamburg. (Port of Klaipeda, 2005.)

Table 14. Lithuanian chemical industry products in 2004.

VI	Products of the chemical or allied industries
28	Inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes
29	Organic chemicals
30	Pharmaceutical products
31	Fertilizers
32	Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints and varnishes; putty and other mastics; inks
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations
34	Soap, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, polishing or scouring preparations, candles and similar articles, modelling pastes, “dental waxes” and dental preparations with a basis of plaster
35	Albuminoidal substances; modified starches; glues; enzymes
36	Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations
37	Photographic or cinematographic goods
38	Miscellaneous chemical products

5.7 Latvia

Latvia is situated on the East Coast of the Baltic Sea. The length of Latvia's Baltic coastline is 490 km, comprising 182 km of Baltic Sea coast to the Lithuanian border and a 308 km coastline along the Gulf of Riga to the Estonian border. The Gulf of Riga and the Irbe Strait are internationally important wintering sites for waterbirds, where the total number in autumn and winter can exceed 2,000,000 birds.

There are 10 ports in Latvia. The three main ones are Ventspils, Riga and Liepaja – all of them mostly working with transit cargoes. Around 90% of transit goes through these ports, mainly from the CIS countries to the west. Latvia is the main transit trade route through the Baltic Sea region. The ports of Ventspils, Riga and Liepaja are ice-free all year round.

The total cargo turnover of Latvian ports in the year 2003 exceeded 54 million tons. Oil and oil products were 42% of the total cargo turnover and bulk chemicals 12%. Chemicals are mainly dry bulk. (Transit Latvia, 2005.) For example, in Liepaja chemical products included bitumen and mineral fertilisers. Bitumen amounted to 37,100 tons in 36 vessels and mineral fertilisers to 78,600 tons in 44 vessels. (State Environmental Service, 2005.)

5.7.1 Ventspils

In terms of volume, Ventspils is by far the biggest port on the Baltic Sea. Its capacity is about 75 million tons and it handles oil, oil products, potash, chemical goods and general cargo. (Transit Latvia, 2005.)

In the beginning of 2000, 20% of the world's potassium (dry cargo; dipotassium pentaoxodisulphate) and 10% of the world's ammonia travelled through Ventspils. The main products also include alcohols, methanol, oil and petrochemicals.

The liquid cargo area of the port has 9 berths ranging in depth between 11.5 m and 17.5 m. These berths can accommodate AFRAMAX type vessels of 130,000 DWT. (Ventspils, 2005.)

Export, 77 vessels

Ammonia (gas)

Sweden	200,000
USA (East Coast)	200,000
Germany	100,000
Norway	100,000
France	100,000
The Netherlands	50,000
Total	***750,000***

Acids in bulk (acrylonitrile, isobutanol, ethyl acetate)

The Netherlands	50,000
Belgium	50,000
Total	***100,000***

AS Ventamonjaks handles various chemical products. It reloads oil products, condensed gas, liquid gas and other liquid cargoes. Chemicals can be stored in 24 tanks ranging from 1,000 m^3 to 44,000 m^3. The total storage capacity of the terminal is 204,000 m^3, ensuring a cargo turnover of up to 2.5 million tons per year. Three deepwater berths can accommodate vessels of 50,000 DWT. (Ventamonjaks, 2005.)

5.7.2 Riga

Nineteen per cent of the cargo handled in Riga is liquid bulk. The products include mineral fertilizers, chemicals and oil products. During last year, MTBE (Metil Terc Buthyl Ether) was transported once, 4,400 tons. In addition to this, vegetable oils are imported to Riga. Amount may be some 100,000 tons (Rikala, 2005). No other data regarding chemical cargoes is available. (State Environmental Service, 2005.)

5.8 Estonia

Estonia is located in the north-eastern part of the Baltic Sea. The length of the Estonian coastline is 3,794 km, of which 1,242 km is on the mainland and 2,552 km is divided among the islands.

Chemicals are not yet widely handled in Estonia. Below are presented two new plans for chemical terminals: Sillamäe and Kunda. There are also plans to start handling chemicals at the Oil Tanking terminal in Muuga (Tallinn). Miiduranna port handled only Russian gasoil (2.23 million tons) as a transit cargo from Russia to the different destinations.

5.8.1 Paldiski

Paldiski is one of the four harbours in Port of Tallinn and it is strongly coming to the Russian chemical transito market. Export from Paldiski consists of xylenes, benzene and isoprenes. Methanol is imported to Paldiski. (Rikala, 2005.)

5.8.2 Sillamäe

The Port of Sillamäe was opened on 14 October 2005. It is located only 12 km from the Russian border. The future plan is to export about 5 million tons of oil and one million ton of chemicals. The capacity within a few years could reach 10 million tons annually (Brodin, 2003).

Sillamäe will have a large terminal for liquid petrochemicals, TankChem. The total reservoir capacity of the terminal amounts to 55,500 m^3. The terminal is expected to be ready by the second quarter of 2006. The total handling capacity of the terminal is forecast to be up to 1,000,000 tons per year.

The terminal project includes

- 3 reservoirs of 12,500 m^3 for methanol
- 6 reservoirs of 3,000 m^3 for different chemical products
- 2 pump stations with working capacity: 500–700 m^3/hour per one line

- simultaneous discharging facility for 22 rail-tank cars carrying different products
- fire safety water pumps station, boiler-house, etc. (as a part of Sillamäe Oil Terminal)
- 5 pipelines to the berths.

The selection of petrochemicals to be handled at the terminal includes

- methanol
- acetic acid
- vinyl acetate
- butyl acetate
- toluene
- monoethylene glycol.

(Port of Sillamäe, 2005.)

The Port of Sillamae is eyed by Estonian businesses as more than a potential competitor to the Ust-Luga port being built in the Leningrad Oblast. While the Ust-Luga port project has been under construction for several years, resulting in just one of the planned eight terminals being built, the port in Sillamae has neared a full launch already this fall. In addition, Sillamae has a natural advantage over its Ust-Luga rival, according to the management of the Estonian port. The Russian harbor stands by a shallow riverbed that is insufficiently deep to serve most cargo ships, the management said. The first part of the Sillamae includes two 16-meter deep oil products quays, one 12-meter liquid chemicals quay, and three 12-meter general cargo quays. (St Petersburg Times, 2005.)

5.8.3 Kunda

In Kunda, all chemical handling in 2004 was export. The total volume was 73,758 tons and it constituted of only one product, shale oil (UN 1288 class 3, according to the IMDG Code). Altogether 21 chemical tankers left for Rotterdam in the Netherlands and Hamburg in Germany.

Baltic Tank Oy is building a chemical terminal in the Kunda harbour. The planned pulp factory will be needing yearly 30,000 tons of liquid chemicals that are not manufactured in Estonia. (Turun Sanomat, 2004.)

The Kunda terminal will begin handling dangerous liquid chemicals with a capacity of 350,000 tons, and the most dangerous chemicals will be methanol, toluene and schistose oil (Virumaa Teataja, 2004).

5.9 Russia

The production of chemical fertilizers is one of the most prosperous branches of the Russian chemical industry. It consists of around 40 plants, which produced just over 20 million tons of nitric, potash and phosphoric fertilizers in 2000. This line of business produces some 20% of the whole production value of the chemical industry, and its share of the export structure of chemical goods is about 45%. (Brodin, 2003.)

Russia's transhipments to the west are mainly chemicals, fertilizers and oil. Transhipments are diminishing as Russia is developing its own ports. (FMA, 2005a.) Russian chemicals go to Central Europe. Part of them is shipped to Asia and the USA.

In Vysotsk, the Lukoil oil terminal is now in exactly the same place as that planned for the chemical terminal. Baltichemexport was bought in its entirety by Lukoil. In St Petersburg, chemical cargo in bulk export in 2004 reached 4.91 Mtons. In Kaliningrad, altogether 270,000 tons of chemicals were handled, most of which were probably chemical fertilizers. (Vasilyev, 2005.)

5.9.1 St Petersburg

When the Russian crop has been bad, vegetable oils are imported through St Petersburg, the amount is some 100,000 tons per year (Rikala, 2005).

5.9.2 Vyborg

In Vyborg, altogether 270,000 tons of bulk chemicals, of which 40,000 tons liquid, were transported in 2004 (Vasilyev, 2005). At least caustic soda is one of the exported products (Rikala, 2005).

5.9.3 Kaliningrad

Kaliningrad, located on the southeast coast of Baltic Sea, is today the only Russian Baltic Sea port that is ice-free all year. It is the shortest transportation route to other Russian regions and the maritime gateway to Eastern Europe. Russia exports glycols and caprolactam from Kaliningrad. (Rikala, 2005.)

5.9.4 Future scenarios

Apart from St Petersburg, Vyborg and Kaliningrad, the Russian ports in the Baltic Sea do not handle liquid chemicals yet. Ust-Luga is located on the southeastern shore of the Gulf of Finland about 120 km west of St Petersburg and 220 km east of Tallinn. At present there is a fertilizer terminal in use in Ust-Luga. Basic construction work for a chemical terminal began already in 1992, but the building of a port at Ust-Luga has been under fierce criticism from environmentalists. Financing has also been a problem. (Brodin, 2003.)

Construction of an LNG plant near St Petersburg

In domestic LNG market headlines, UK-based oil major BP could take part in the construction of a liquefied natural gas (LNG) plant in the Leningrad region, the press office of Gazprom (RTS: GAZP) reported after a meeting held between Gazprom's BoD chairman Alexey Miller and BP CEO Lord John Browne. At the meeting the top executives spoke about cooperation of the Russian gas monopoly and the British oil major on the European gas market, including the possibility of BP's involvement in the erection of an LNG facility in the Leningrad region, the press release said. Addressing the prospects of bilateral cooperation, the parties expressed satisfaction over LNG supply relations. As reported earlier, Gazprom's partners in building an LNG plant in Primorsk (Leningrad region) are Canadian Petro Canada and Sovkomflot. (Nov. 23, 2005 Finam.)

6. Brief analysis on chemical outflow and spreading

6.1 The substances carried in the Baltic

The most important chemicals transported in the Baltic Sea are listed in Table 15.

*Table 15. Chemicals transported in the Baltic Sea (the ones written in **bold** are the most common).*

Product	Marpol class	Other	Behaviour classification
Acrylonitrile	B		Dissolver/Evaporator
Ammonia	gas		Gas (=Evaporator)/Dissolver
Acetone	Appendix III		Dissolver/Evaporator
Benzene	C		Evaporator
Butadiene, Vinylethylene	gas		Dissolver/Evaporator?
Coal tar	A		
Epichlorohydrin	A		Dissolver/Evaporator?
Ethanol	Appendix III		Dissolver?
Ethylene glycol	D		Dissolver?
Phenol	C		Dissolver
Phosphoric acid	D		Dissolver
Xylenes	C		Floater/Evaporator
Methanol	D	flammable liquids	Evaporator/Dissolver?
Formic acid	D		Dissolver
Sulphuric acid	C		Dissolver
Styrene monomer	B		Floater/Evaporator?
Nitric acid, hydrogen nitrate	C		Dissolver

Nonylphenol ethoxylate	B	corrosive substances	Sinker/Dissolver
Caustic soda	D	corrosive substances	Dissolver
Tall oil	B		
Toluene	C		Floater/Evaporator
Vinyl acetate	C		Evaporator/Dissolver

After discussion with the project's steering group, the following substances were chosen for further analysis. The seven important chemicals are thoroughly presented in Appendix G.

1. Vinyl acetate (C) – One accident has happened in Scotland.
2. Soybean oil (D) – Even though vegetable oil doesn't sound that bad, it is nonetheless harmful to birds and other animals as is any other oil. There is a biodiesel plant under construction in Sköldvik which will increase the transportation of vegetable oils in the Baltic Sea.
3. Epichlorohydrin (A)
4. Ammonia (gas)
5. Styrene monomer (B)
6. Ethanol (App. III) – Is widely used in biofuel plants in Sweden.
7. Methanol (D)

6.2 The risk of chemical outflow from a damaged ship

Almost all the public papers of tanker outflow analysis are based on oil outflow. The data on chemical outflow estimations is very scarse. When studying the possibility of accidental oil outflow from a tanker, two main damage sources can be found: collision and grounding. Two other, rare, causes of accidental oil outflow are fire onboard and explosion/s. Here the focus is on collision and grounding only, because fire and explosions onboard are so difficult to categorise and handle, and the expected magnitude of the oil outflow could be anything between zero to total loss, depending on the case and how it develops onboard.

Referring to (Luukkonen, 1999), around half of the grounding accidents in Finnish territorial waters took place in the Archipelago or involved a narrow fairway. Taking into account both collisions and groundings, collisions represented around 68% of the total amount of accidents in Finnish waters during the years 1978–1985. This highlights the effect of the narrow and shallow fairways of the Finnish coastline and Archipelago Sea.

Damage can be divided into the following sub-classes:

- collisions between two ships (at least one ship is moving)
- collisions between a ship and an offshore structure
- collisions between a ship and a fixed harbour construction
- collisions between a ship and man-made islands
- collisions between a ship and submerged soil/rock, i.e., grounding.

The most essential difference between collision and grounding is that in groundings friction plays a significant part. Usually one of the ships is moving also in the collision mode, but rocks or the sea bottom do not have any kinetic energy, and all transformations take place in the ship.

In the case of grounding accidents the double-bottom construction gives additional safety against rock penetration through bottom plates, thus preventing the loss of stability or the outflow of oil. If a large part of the ship's kinetic energy goes into the transformation process of the plate, the damage can be classified as a "high-energy" case, leading to the loss of water-tightness. If the tank compartment remains untouched after direct damage, the case is called a "low-energy" grounding (or collision). However, if the ship remains on the rock or a shallow embankment after the initial grounding, the remaining longitudinal strength of the ship can be significantly reduced, thus leading to the risk of break-down of the ship.

The different mathematical formulas to evaluate the grounding phenomenon and to estimate the forces related to the grounding have been presented in (Kaila & Luukkonen, 1998).

The principal elements associated with a collision can be defined as (Daidola et al., 1997) follows:

- nature of collision – collision with a rigid object or another vessel
- intensity of collision – speed, displacement, bow shape, draft, relative orientation of the striking vessel or object
- condition of struck tanker, displacement, draft, speed, relative orientation
- environmental conditions, wind, wave, current
- structural resistance to collision.

For the grounding mode, the following dominant elements can be found:

- characteristics of the grounding obstruction – vertical location of area below free surface, structure, shape and size, environment
- condition of grounded tanker – draft, displacement, speed
- structural resistance to bottom deflection and/or raking damage (obstruction tears open the outer plating as the ship is moving).

Grounding can also be studied in the time-domain: an initial grounding mode can be found that illustrates the primary impact when grounding. The next mode could be defined as the raking damage mode, where the ship moves over the submerged obstruction, which cuts the bottom/side plates open. Finally the post-grounding mode can be defined, where the ship is stopped, lies on the obstruction or on-shore and faces new impacts due to the surrounding hydrodynamic forces. There are a lot of known cases where the initial grounding (and collision) of the ship caused minor outflow or damage, but due to the severe wave phenomena, damaged construction and ship motions, the ship was totally destroyed, leading even to total loss (for example MT Braer).

Appendix H gives an estimation of the potential oil or chemical outflow based on the IMO’s Marpol Annex I Regulations 13F and 13G in the case of single hull tankers subject to a certain set of pollution prevention measures during the retrofitting phase. The detailed list of pollution prevention measures is shown in Ref. (Daidola et al., 1997). Regulation 13F used herein is a modified version of (Daidola et al., 1997) where a certain development module of 13F has been utilised. Regulation 13F applies to new vessels while 13G applies to existing vessels. These regulations provide an estimate of the average or mean outflow due to accidental collision or grounding based on observations of past accidents. Additionally, the extreme outflow columns of Appendix H represent the average of the 1/10 highest outflow events.

It should be noted here that some scientific papers conclude that the IMO's interim Guidelines for Approval of Alternative Methods of Design and Construction of Oil Tankers in Collision and Grounding (Regulation 13F) severely underestimate the grounding damage to the bottom structure of larger vessels and to a lesser extent overestimate the collision damage to the side structure of the hull (Pedersen & Zhang, 2000).

When studying Appendix H, the following conclusions can be made:

- In Baltic Sea conditions, the Regulation 13F mean outflow/bottom columns are only valid for a tidal drop of 0 m.
- Regulation 13F gives for 40,000 dwt and 71,000 dwt tankers a total mean outflow of roughly 2,500 and 4,500 m^3, respectively.
- For existing tankers (Regulation 13G) the corresponding outflow rates for 40,000 dwt and 71,000 dwt tankers are roughly 1,500 and 3,500 m^3, respectively (total outflow).
- The total extreme outflows for 40,000 and 71,000 dwt tankers according to Regulation 13 F are around 6,000 and 12,000 m^3.

These figures would mean that for an Aframax-class tanker of 95,000 dwt having 111,111 m^3 oil onboard the extrapolation according to Regulation 13G gives an outflow rate of roughly 4,700 m^3. The total extreme rule would already give an outflow rate of close to 16,000 m^3. Regulation 13G leads to the following conclusions:

- The mean total outflow for a tanker of 71,000 dwt is roughly 3,000 m^3 in the worst class, while the best tank construction will give around 1,500 m^3.

– This means that for a 95,000 dwt tanker the corresponding outflow range is between 2,000 and 4,000 m^3.

The extreme outflow range for a 40,000 dwt ship varies between 7,000 and 12,000 m^3, depending on the tank arrangements and pollution prevention measures. Thus for a 95,000 dwt ship, the extreme outflow range is 9,300–16,000 m^3. The reader should be note, here that these figures suit for the oil tankers, while the expected outflow rates of chemical tankers are significantly smaller.

Example related to chemical tankers

A method to evaluate the Accidental Oil Outflow rate is shown in (Herbert Engineering Corp., 1998). The method was applied there to a series of double hull tanker designs, which cover a broad range of sizes, cargo tank arrangements, and wing tank and double bottom dimensions, see Table 16.

The study covered 96 designs. The cargo deadweight at 98% filling (MT) covered classes from 5,000 tons up to 450,000 tons. In Baltic Sea conditions the size 150,000 tons also used in this study is already too big, thus the size 100,000 tons is considered here an upper limit.

Figure 11 presents a typical 6 x 2 (6 tanks long by 2 tanks wide) cargo tank arrangement, with an L-type ballast tank design. A nominal cargo oil density of 0.885 t/m3 was assumed for all designs used in this study, thus the following design table for the main particulars was given.

Figure 11 illustrates the tank configuration of an oil tanker and Figure 12 that of a chemical tanker.

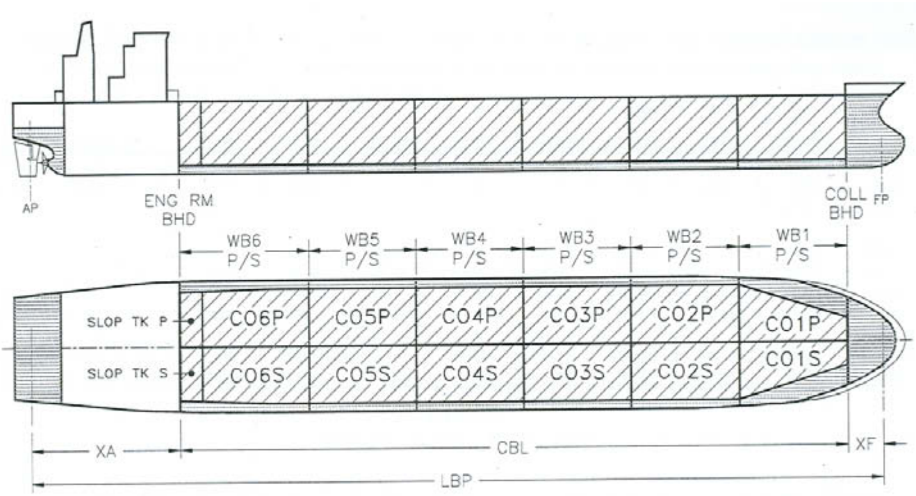

Figure 11. Typical cargo arrangements of an oil tanker (Herbert Engineering Corp., 1998).

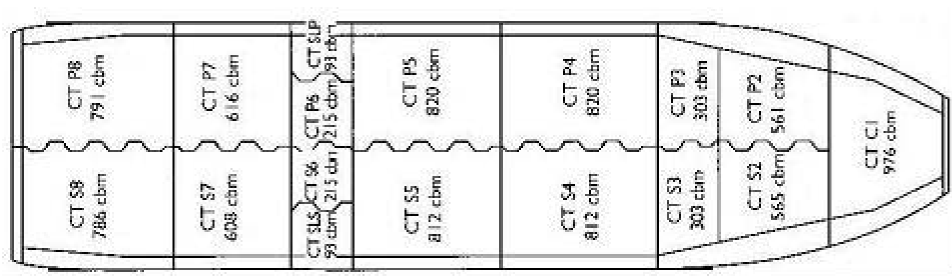

Figure 12. Typical cargo arrangements of a 10,000 dwt chemical tanker (Crystal Pearl).

Table 16. Baseline Design Particulars (Herbert Engineering Corp., 1998).

Cargo dwt [MT]	5,000	40,000	60,000	95,000
Cargo tank arrgt	6x2	6x2	6x2	6x2
Wing tank [m]	1.00	2.00	2.00	2.00
Double bottom ht [M]	1.10	2.00	2.00	2.00
LBP [M]	95.00	170.25	203.50	235.20
Beam (moulded) [M]	16.50	30.96	36.00	41.80
Depth (moulded) [M]	8.30	17.03	18.0	19.80
Full draft (moulded) [M]	6.20	11.72	12.20	13.79
98% Cargo capacity [m3]	5,848	46,784	70,175	111,111
Cargo oil density [MT/m3]	0.855	0.855	0.855	0.855

Increased wing tank clearances tend to improve environmental performance, i.e., to reduce mean outflow and increase the probability of zero outflow. The outflow calculations in this study assumed a nominal double bottom, and wind tank clearances were exactly maintained throughout the cargo block.

The results of the calculation showed in this reference are showed in Table 17 for the tanker capacities of 5,000 and 40,000 metric tons below.

Table 17. The oil outflow results.

Cargo DWT	*Cargo Tank Arr.*	*WT x DB [m]*	*Side QMS*	*Bottom QMB*	*Total QM*	*98% Cap. [m3]*	*Mean Outflow parameter Qm/C*
5000	5 x 2	1,0 x 1,1	115	68	87	5,849	0,0148
		1,25 x 1,25	89	61	72	5,849	0,0124
		1,5 x 1,5	73	52	60	5,849	0,0103
	6 x 2	1,0 x 1,1	102	64	79	5,849	0,0136
		1,25 x 1,25	79	57	66	5,849	0,0113
		1,5 x 1,5	65	49	55	5,849	0,0094
	7 x 2	1,0 x 1,1	93	61	74	5,849	0,0126
		1,25 x 1,25	72	55	62	5,849	0,0106
		1,5 x 1,5	59	46	51	5,849	0,0088
40 000	5 x 2	2,0 x 2,0	898	526	675	46,784	0,0144
		2,25 x 2,25	785	493	609	46,784	0,0130
		2,5 x 2,5	694	460	554	46,784	0,0118
	6 x 2	2,0 x 2,0	797	491	613	46,784	0,131
		2,25 x 2,25	696	460	555	46,784	0,0119
		2,5 x 2,5	616	430	504	46,784	0,0108
	7 x 2	2,0 x 2,0	724	468	570	46,784	0,0122
		2,25 x 2,25	633	438	516	46,784	0,0110
		2,5 x 2,5	560	409	470	46,784	0,0100

Figure 13 below gives the graphical form of this calculation. The proposed standard for calculation of the mean outflow is shown by a dashed line. The letter x shows the corresponding outflow parameters defined by the IMO regulation, Marpol I/22–24.

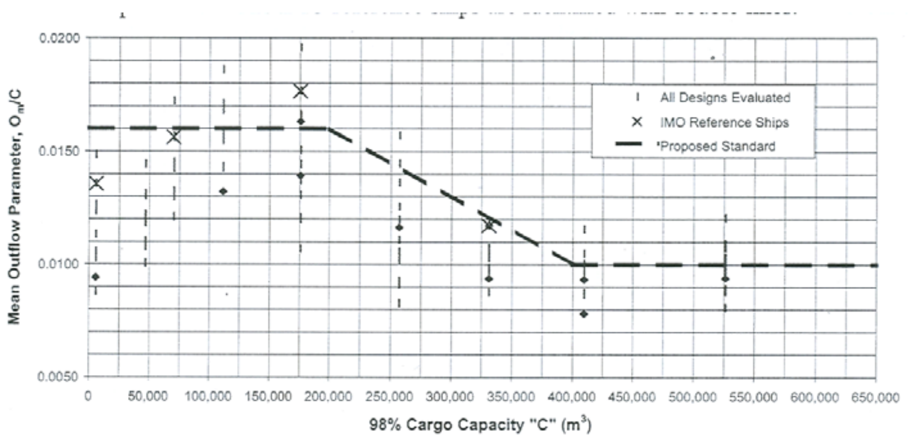

Figure 13. The oil outflow results (Herbert Engineering Corp., 1998).

The IMO Marpol rule, regulation 22, defines the calculation formula for side and bottom damage with certain coefficients for longitudinal, transverse and vertical extent. Regulation 24 lays down restrictions on the size and arrangements of the tanker's cargo tanks based on the outflow calculations. Thus if the ship complies with the regulations, the design tanks' capacity and the expected mean outflow rate will match, giving an indication of the expected oil flow rate in an accidental situation.

Due to the fact the usual size of the chemical tanker sailing along the Baltic Sea water is within the range of 5,000–10,000 dwt, the expected outflow rate is a lot of smaller than in the case of an oil tanker. Additionally, due to the larger amounts of cargo tanks, the outflow rates are also smaller compared to the same sized oil tankers. Thus, it can be concluded, that the expected mean outflow rates of a chemical tanker for grounding and collision modes are in the range of 50–200 tons.

6.3 Risks related to winter navigation

Here the special questions related to winter navigation have been highlighted with the help of the ice damage observed during winter 2003 in Finnish waters. The initial work was done by the research scientists of the Helsinki University of Technology, and the detailed report is given in (Jalonen et al., 2005). A quicker presentation of the subject can also be found from (Hänninen & Jalonen, 2003).

The winter of 2003 lasted a few weeks longer than usually. In many areas there was thick ridged and rafted ice, and the maximum ice cover extent corresponded roughly to the long-term average, which in fact is close to two times greater than the average maximum extent of the past decade. This reflects the fact that the past winters have been mild and the ice thickness and extent have been a much smaller than normal according to long-term statistics. In all there were 9,013 port calls during the observation period, and the following damage table could be made based on the damage reported. Note: the same ship may have sustained different types of damage. The damage conditions and the ships included in Table 18 are shown in Figure 14.

Table 18. Damage types in winter 2003 (Hänninen & Jalonen, 2003).

DAMAGE TYPES	NUMBER OF OBSERVATIONS
dents and failures due to ship-ice contact	30
ship collisions in ice	23
grounding events due to difficult ice conditions	3
ships in bad condition or inadequate ice strengthening	5
propeller damage	36
rudder damage	7
surface damage (painting)	3
main engine or other machinery malfunction	3

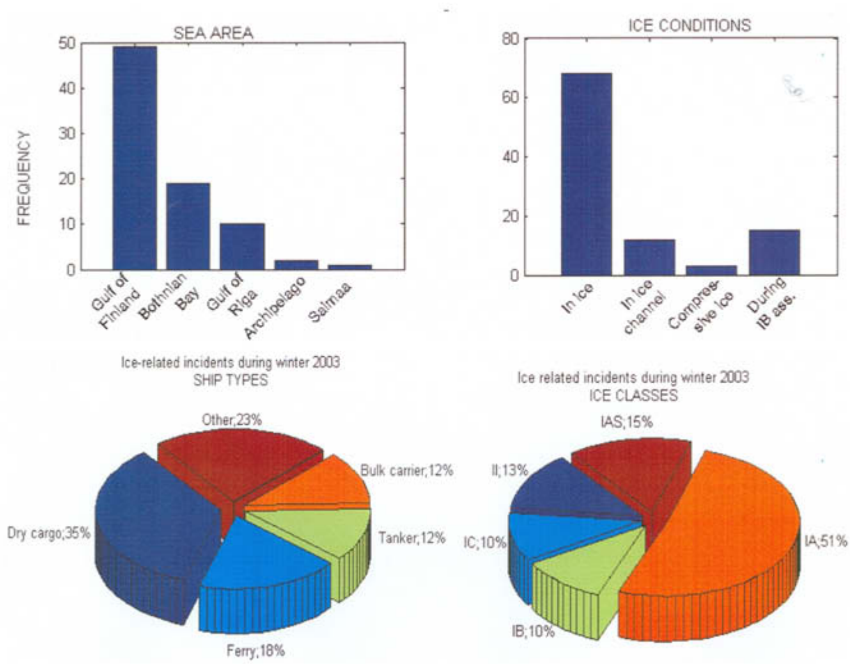

Figure 14. Damage conditions and the ships involved (Hänninen & Jalonen, 2003).

As can be seen from Figure 14, the most critical winter area for ice damage was the Gulf of Finland, while the Riga Bay was the least critical, mainly due to easier ice conditions and lesser traffic. Most of the damage occurred in ice, while incidents in the ice channel and assistance-related damage with ice breakers played a significant role, too.

The experiences gained in 2003 showed that ice damage does not only include direct hull damage but extensive rudder and propeller damage, too. Serious hull damage is rare. When analysing the ship types involved, the observation can be made that tankers were involved in 12% of the total amount of incidents. Due to increasing oil transports especially in the Gulf of Finland environment (Hänninen & Rytkönen, 2004), it can be estimated that the frequency of tanker-related incidents will increase in winter navigation in the future.

Based on the lessons learned in 2003, the general statement was made that about 10% of the ships visiting Finnish ports had some sort of ice damage, and that the damage occurred in 1% of the voyages. The probability of ice damage / voyage was estimated to be 0.7% for Ice Class IA and IAS. For Ice Class II and IC the probability of ice damage was estimated to be 6.0%. Ice classes II and IC thus suffer ice damage about 9 times more often than ice classes IA and IAS. Figure 15 and Figure 16 show examples of some of the damage observed.

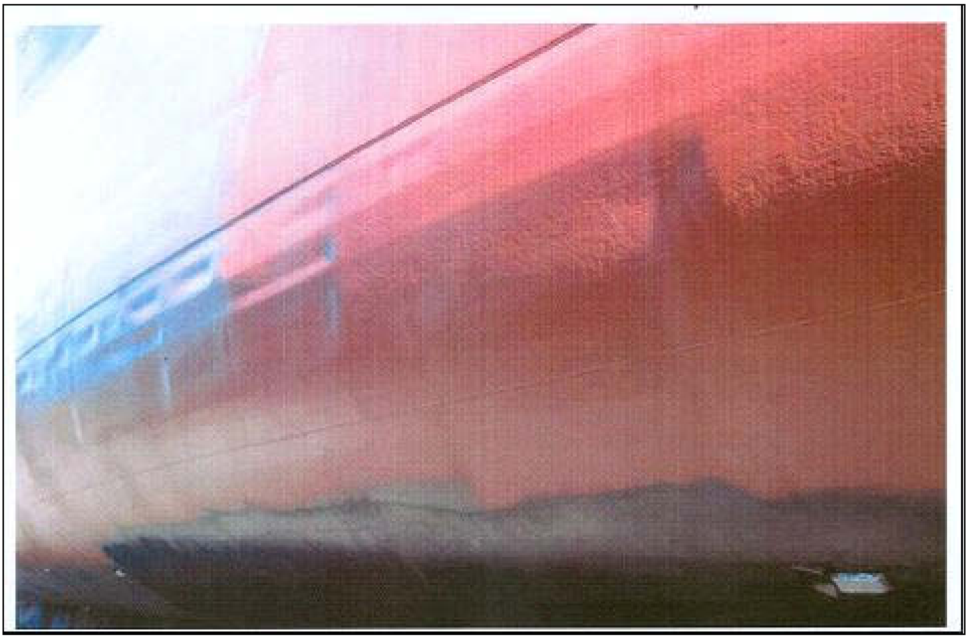

Figure 15. Observed damage to a chemical tanker of 22,700 DWT, ice class IA in winter 2003. The damage type is up to 25 mm deep dents on mid ship below the ice belt. Plate thickness of the ship was 14 mm, frame spacing 800 mm, frame span 2.4 m (Hänninen & Jalonen, 2003).

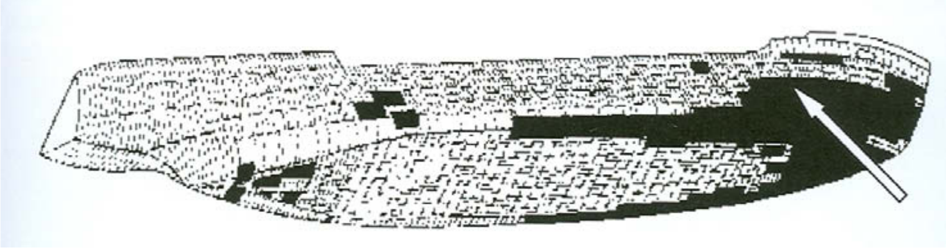

Figure 16. Typical locations of hull ice damage on Arctic ships presented here in black. The bow shoulder area is marked with an arrow (Jalonen et al., 2005).

The risk of winter navigation in the northern Baltic Sea has been assessed in (Jalonen et al., 2005). The report states that based on the period 1975–2000 winter navigation poses a rather small risk to shipping. The average frequency of ice damage, incidents or accidents is significant, but consequences are rather slight. Most of the accidents and incidents related to ice have minor consequences, and very rarely do any spills take place due to this damage.

The report (Jalonen et al., 2005) divides the total risk of winter navigation into three main categories, i.e., the risk for people, for the environment and for property, as can be seen from Table 19.

Table 19. Risk of winter navigation in the northern Baltic Sea (Jalonen et al., 2005).

Winter classification	Fatalities	Pollution	Total loss
mild winter	once in 40–75 years	once in 8–17 years	once in 12–20 years
normal winter	once in 10–20 years	once in 2–5 years	once in 2–5 years
severe winter	once in 3–6 years	yearly	once in 1–2 years

The table above contains plenty of assumptions and uncertainties that may influence the results: some of the linearisations made and the assumptions dealing with ice class classifications may alter the results. However, the work done is based on rather long-term data on ice-related damage, and thus it gives reliable information about the expected incidents. In Figure 17, icebreaker Urho is assisting a chemical tanker in the Gulf of Finland.

In the pollution risk class for the generic ship type used in the evaluation, the probability of environmental damage is greatest in the case of hull ice damage and grounding. The combined risk level is equal to about one spill in approximately two years, if spills of all size categories due to hull ice damage and grounding are taken into account.

Figure 17. Icebreaker Urho assisting a chemical tanker in the Gulf of Finland. Photograph courtesy of Finnish Maritime Administration.

6.4 Spreading scenarios and basic fundamentals to control spilled chemicals

6.4.1 The fate of chemicals spilled on water

The physical and chemical processes related to chemicals spilled out of a tanker can be divided into four main categories (Salo, 1992):

- evaporation and entrainment to the air
- dissolution and entrainment to the water mass
- spreading and transportation
- chemical reactions.

The vapour pressure determines how fast a liquid substance will evaporate and mix with the atmosphere. The solubility of a particular chemical describes how much it will mix with water. However, here the mixing velocity is not included; it is dependent on the energy brought to the process (wave patterns, for example). Solubility is the most dominant physical reaction (Oebius, 1992) from the point of view of controllability. This is also the weak point of the controllability tool selection due to the uncertainties concerning the fate of the chemical.

The viscosity of a chemical characterises the deformation velocity of a substance under a certain force field, including the distortion and the destruction of a chemical cloud. Finally, the surface tension determines the tendency of a liquid to obtain the position of the individual molecules (Oebius, 1992). This illustrates the tendency to form droplets on the water–chemical interface, or to spread into a thin film-type layer, expressed as a negative or positive spreading coefficient.

If a chemical spill occurs, it is important to know the environmental fate of the spilled chemical. The chemical released from a tanker in an accidental situation may spread and drift by action of the wind and sea currents. It may also dissolve into the water, or form a chemical-in-water emulsion or be dispersed into the water mass, normally due to the wave phenomenon. Some chemicals may also sink to the bottom and affect the food chain of the bottom animals and fish.

6.4.2 Evaporation and entrainment to the air

The evaporation rate of chemicals is a function of temperature, wind speed, atmospheric conditions, solar radiation, the dimensions of the spill and the volatility and diffusion characteristics of the chemical.

The total mass transfer process during evaporation can be divided into liquid phase mass transfer resistance and vapour resistance. Liquid phase resistance controls the rate of the transfer of material from the bulk of the liquid to the interface and depends on the eddy and molecular diffusivities and on the flow conditions of the liquid. Vapour resistance controls the rate of the transfer of material from the interface to the atmosphere. Reference (Salo, 1992) gives some theoretical formulas to evaluate the evaporation rates of chemicals.

However, most of these formulas were developed for oils and hydrocarbons, thus their relevance for other types of chemicals is not well defined.

Many gases are transported as refrigerated or pressurised liquids (for example LNG). The failure of the container or cargo tank of the vessel leads to the evaporation of the liquid. The generation of vapour is a complicated phenomenon to evaluate mathematically. However, presentations can be found in literature dealing with cryogenic liquids and pressurised liquids, and there are spreading models and plume models available for operational usage.

6.4.3 Dissolution and entrainment to water columns

Depending on the physical and chemical nature of the chemical, it may dissolve, disperse or submerge. Gases will also dissolve in water. The dissolution rate is limited by solubility and the rate at which the dissolved molecules are transported by diffusion or mixing in the water mass. The wave phenomenon increases heavily the molecular diffusion process compared with mass transport by molecular diffusion alone.

Solubility is an important parameter here due to its relevance both in the dissolution of chemicals and in mass transport from the water body to evaporation. Dispersion characteristics are a well know phenomenon in oil spills. Special detergents are developed for oils to get the oil slick to disperse into the water column. These detergents called dispersants are favourable in deep ocean-like conditions, but in shallow areas like the Baltic Sea, the combined impact of dispersants and dispersed oil may have acute and/or chronic effects on micro-organisms and fish. However, there are other chemicals, too, that have the tendency to disperse when first spilled on the sea surface. In rough sea conditions, the turbulent conditions caused by wind and waves will increase both the size of the dispersed droplets and the amount of chemicals dispersed into the water column.

6.4.4 Spreading and transportation

Spilled chemicals are spread by wind and currents, but they also spread by diffusion, buoyancy difference between the water and chemical. There are three main processes: surface spreading, vertical dispersion and horizontal dispersion.

When evaluating the behaviour of spilled chemicals in nature, special attention should be paid to the evaluation procedure used. There are many parameters in the full-scale situation which may alter the analysis based on chemical characteristics and behaviour studies in laboratory-scale tests. Many test results are based on the analyses made on the laboratory-scale with dimensions such as shaker test bottles. However, in large-scale accidents, tons of chemicals may be released into the environment where the temperature, wind conditions and thus the prevailing wave phenomenon may change markedly the observed behaviour of the spilled chemical compared to the prognoses made based on laboratory-scale testing only.

6.4.5 Controlling the chemical spill

When trying to prevent the chemical from spreading to a larger area, the same methodologies as in oil combating can be used. This is true if the chemical in question remains on the water surface and acts like floating oil slick. However, there are plenty of factors limiting the success of recovery operations if only oil recovery systems are used. Many of the chemicals transported in liquid form may develop gases or poisonous fumes, making the combating work more dangerous for the personnel involved and increasing the need for stringent safety and security requirements.

The basic ways of controlling a chemical slick once it starts to spill out, float and spread into nature can be classified as follows:

- passive methods, usually booms and barriers
- active recovery methods
- other means, such as dispersion
- control of sinking agents and chemicals.

The fifth element here is the detection of the chemical after it has spilled out: the chemical may mix with the water column partly or totally, thus making it impossible to perform any control operations. The chemical may also be transparent, in which case visual observation during the recovery work is impossible. The chemical may evaporate, be submerged or totally sink down to the bottom.

If a chemical that has spilled out starts to burn or poses a risk of explosion, the preventive methods can also be characterised as control methods. However, this has not been discussed in this publication. There is a great deal of literature on the use of various technologies to recover oil or liquid chemicals. The reader is encouraged to see for example (Oebius, 1992; HELCOM, 2002).

The characteristics of a floating chemical may also differ from the typical characteristics (density, viscosity, pour point, etc,) of oils, making certain recovery options irrelevant. For example, a rotating brush-type system may collect oil well but not chemicals. Thus selecting the appropriate method for a chemical spill is always case-by-case work demanding a lot of experience in combating work and the chemical's behaviour in water.

Floating chemicals, as opposed to mineral oils and oil derivates, are usually transported in pure form, and they are characterised by their physical and chemical properties. Chemicals, once released into the water, can appear in gaseous, liquid or solid form as evaporators, floaters, dissolvers or sinkers.

Floating chemicals, for example, are only controllable if the vapour pressure of the chemical does not exceed $P_D < 300$ hPa, and the solubility is negligible if $s << 1\% < 10$ mg/l. Other rules of thumb for chemical controllability are the following:

- The density must be small enough compared with water to give sufficient buoyancy to the floating liquid, or large enough to support the sinking process.
- The spreading coefficient from the comparison of surface and interfacial tensions is negative.
- The substance must be visually or technically detectable.

More than 300 chemicals were classified in 1986 in the Kiel Channel in Germany (Oebius, 1992), and around 110 chemicals were identified as liquid chemicals. Of these liquid chemicals 2% were classified as evaporators, about 50% as floaters, approximately 42% as dissolvers and finally some 7% as sinkers. Sinkers have been classified here as chemicals having a density larger than 1.025 g/cm^3, a relative solubility of $s < 0.1\%$ and a vapour pressure of $P_D < 1013$ hPa. Even if sinkers are usually outside the reach of the control measures once submerged, there are case studies where the sunken material has been successfully lifted up from the sea bottom. As with floating chemicals, there are a set of technologies available both in passive and active recovery classes to control the sunken spill. Burying the sunken chemical can also be used as a control method if this method proves to be the most advantageous in a specific case.

Casualties involving chemical tankers in the Baltic Sea environment can be classified into four classes:

1. The casualty happens in open sea conditions.

2. The casualty takes place close to the coastline, or close to sensitive areas such as archipelagos.

3. The casualty takes place in a closed area such as a harbour or terminal area.

4. The casualty takes place during the winter time in the presence of ice and snow.

This classification is made by the authors of this publication for the following reasons and taking into account the special features of the Baltic Sea:

- There is in practice no tidal variation in the Baltic Sea, thus this driving force can be neglected as an important parameter affecting the controllability of a chemical spill. However, in the rest of the world the tidal phenomenon is one of the most important driving forces in combating operations, and especially in the case of shore protection and beach cleaning activities.
- Open sea conditions (1.) usually characterise conditions where the spill has more time to spread, dissolve or vaporise. It will also take more time for response units to reach the accident site and to undertake protective measures, such as booming, lightening operations and recovery works. The

open sea area is also more sensitive to wind and waves, and in rough conditions there are technically very limited possibilities to work sufficiently close to the damaged ship to control the situation. However, if the spilled chemical has the tendency to evaporate or dissolve, it will mix with the larger water masses more rapidly and thus have a less fatal impact on the environment. In certain cases, large amounts of chemical mixed with the sea water will increase the chronic toxic level before the concentration level due to the accident has reached the background level once more. In open sea conditions, the most critical factor is the time needed to get to the site and start to prevent leakage into the surrounding environment.

- Coastline and archipelago conditions (2.) usually give two scenarios for controllability: first the surrounding islands and the coastline offer a place of refuge where the damaged ship can be towed or where booming measures can be taken successfully. However, these environmental conditions also pose an increased environmental risk of pollution: the coastline and archipelago environment is a habitat for marine organisms, fish, waterfowl and seals and is also the site of human activities. Thus if the chemical spill has the time to spread widely, the consequences would be significantly larger than in open sea conditions. It is a well known fact in European conditions that the recovery costs for the enlightening operations: recovery in open water: beach cleaning activities are 1:10:> 100. The impact evaluation may be even more severe, such as 1:10:> 1 000.
- The casualties in harbour or terminal area (3.) can usually be restricted by the port and terminal personnel. Usually the spill site can be effectively localised, on condition of course that the detection has been made in time and the recovery actions have been started in a proper manner. In the case of chemicals dissolving in the water mass, however, large-scale spillage can cause severe local acute toxicity, which will cause the total loss of marine organisms in the accident site. There are reports on accidents in terminal areas, where the local spill has first killed fish, microorganisms and waterfowl, but gradually due to mixing the concentration level has decreased below the lethal level or some preventive measures have been taken to reduce the impact. The terminal and port areas on the other hand create increased risks for humans working nearby, if the chemical spill causes heavy gaseous formations, a smoke plume, etc.

- Winter conditions (4.) characterise chemical spills in the northern part of the Baltic Sea. The dominant factors here are the low temperature and the presence of ice and snow (Figure 18).

Figure 18. Chemical tanker in ice. Photograph courtesy of Crystal Pool.

The cold environment changes significantly the viscosities of the chemicals, thus affecting the recovery efficiency of a large set of mechanical units. Oils and oil-like chemicals in cold, for example, will act more like a pseodoplastic solid mass than a fluid, and techniques based on a fluid-like mass are no longer effective. High-viscosity pumping techniques and brush recovery systems are usually the best available technologies for ice and cold climate. The surrounding ice and snow will also make it difficult for the recovery fleet to operate. The detection of chemicals is also difficult, and if the chemicals go under the ice, in practice only limited operations can be performed in the accident site. Ice breakers may offer here some possibilities for improved mixing of the chemical with the larger water mass, i.e., they may enhance mixing with their propellers and movements if this kind of activity is suitable. Usually efforts to use dispersing agents to disperse oil or other chemicals to larger water masses are ineffective due to the lack of mixing energy and to the presence of protective ice and slush.

7. Improving safety of marine chemical transportation

Chemical tankers are among the safest ships afloat. One reason for this is the action taken by the industry and governments to adopt and implement stringent regulations regarding both safety and pollution prevention. IMO conventions are presented in Chapter 3, but some other means to improve the safety of chemical transportation in the Baltic are discussed here.

7.1 Finland's Baltic Sea protection programme

In 2002, the Finnish government gave a resolution on action for conservation of the Baltic Sea in "Finland's Baltic Sea protection programme".

The aim of the programme is to reduce eutrophication in the Baltic Sea and to improve the condition of the waters and maritime flora and fauna. Discharges of hazardous substances should not cause harm to the ecosystem of the Baltic Sea or to human health. The use of natural resources in the area shall be based on sustainable development. Oil and chemical transportations and the operation of the large oil harbours shall be pursued with the aim of minimising risks and the impact of possible spills on the marine environment. Illegal deliberate discharges of oil shall be stopped.

Action is needed both in Finland and in neighbouring countries. The constant increase in tanker shipping has considerably raised the risk of environmental accidents at sea, especially in the Gulf of Finland. The eastern part of the Gulf in particular is in need of more capacity for combating oil and chemical spills, for lightening chemical loads, for emergency towing, for firefighting and for combating oil spills when the sea is covered in ice. Readiness must be improved in Finland, Russia and Estonia, and joint combating exercises must continue to be organised. A high standard of safety shall be ensured for oil and chemical transportations in the Baltic Sea.

A multipurpose oil and chemical combating vessel shall be provided to improve pollution prevention capacity in the eastern part of the Gulf of Finland. In spite of the good intentions, the vessel has not been ordered yet. In the long term, oil pollution prevention and combating readiness shall be further improved by acquiring vessels suitable for winter as well as open-sea conditions, to be stationed also in the Gulf of Finland. Readiness for preventing chemical and oil pollution in Russia and Estonia shall be improved in co-operation with neighbouring areas, so as to bring the readiness to the level required by the increased risks.

In order to reduce illegal deliberate dumping of oil at sea, preparatory work for the introduction of administrative sanctions or other penalties shall begin. Provision of reception facilities for oil waste from ships in ports shall be promoted in international co-operation. (Finland’s Environmental Administration, 2005.)

7.2 EU activities

7.2.1 European Maritime Safety Agency

The European Maritime Safety Agency (EMSA) was created in the aftermath of the *Erika* disaster. Its goals are to reduce the risk of maritime accidents, marine pollution from ships and the loss of human lives at sea. The Agency will provide technical and scientific advice to the Commission in the field of maritime safety and prevention of pollution by ships in the continuous process of updating and developing new legislation, monitoring its implementation and evaluating the effectiveness of the measures in place. Following major shipping disasters in European waters, such as the sinking of the ferry *Estonia* and the tankers *Erika* and *Prestige*, very substantial packages of EU legislation have been adopted to improve maritime safety and to reduce pollution from ships.

As of May 2004, with the entering into force of Regulation 724/2004, the European Maritime Safety Agency has a legal obligation in the field of response to ship-sourced pollution within the Community. EMSA has identified four priority areas in European waters, and the Baltic Sea is one of those. EMSA’s action plan (EMSA, 2004) is mainly focused on oil pollution prevention. EMSA is required, if requested, to assist coastal states in case of large-scale incidents such as the *Erika* accident in December 1999 and the *Prestige* accident in

November 2002. The primary responsibility to react to an incident remains with the member state concerned.

EMSA's activities in the field of combating marine pollution are focused on ship-sourced pollution. During the year 2005, EMSA's aim was to develop its role along three distinct lines (EMSA, 2004):

- operational assistance
- co-operation and co-ordination
- information.

7.2.2 Third maritime safety package, "Erika III"

The European Union acted immediately following the Erika and Prestige accidents to set up a "defensive" mechanism to protect Europe against the risks of accidents and pollution. With the third maritime safety package, the Commission is today proposing a more proactive policy aimed at restoring conditions for healthy and sustainable competition for those operators who comply with international rules.

The third maritime safety package contains seven proposals structured around two major themes: 1. Improved accident and pollution prevention and 2. Dealing with the aftermath of accidents. (EU, 2005a.)

The seven proposals (listed below) contained in the package are intended to supplement the European rules concerning maritime safety and improve the efficiency of the existing measures. They take account of the experience acquired in implementing the Community legislation on maritime safety (the Erika-I and II packages and the measures adopted following the Prestige accident), and the concerns expressed on several occasions by the European Parliament, the European Council and the ministers of transport.

1. A proposal for a Directive on the conformity requirements of flag states
2. Amendment of the Directive on classification societies

3. Amendment of the Port State Control Directive

4. An amendment of the Traffic Monitoring Directive

5. A proposal for a Directive on accident investigations

6. A Regulation on liability and compensation for damage of passengers in the event of maritime accidents

7. A Directive on the extra-contractual liability of shipowners

(EU, 2005b.)

7.2.3 European Council Directives

Below are just a couple of examples of the EC directives that apply also to liquid chemical transportations.

SafeSeaNet (SSN)

The Commission has initiated the development of a Europe-wide communication system that is able to track and follow ships and obtain information on their cargoes (in particular when hazardous substances are being transported). This system, called SafeSeaNet (SSN), will facilitate the identification of vessels and action to be undertaken by authorities after an incident or accident. It is expected that the majority of countries participating in the SSN system (20 EU coastal states plus Norway and Iceland) will have successfully completed the required tests by the end of 2005. SafeSeaNet has developed a Community vessel traffic monitoring and information system according to Directive 2002/59/EC (EU, 2002).

Community vessel traffic monitoring and information system

Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC (EU, 2002).

The purpose of this Directive is to establish in the Community a vessel traffic monitoring and information system with a view to enhancing the safety and efficiency of maritime traffic, improving the response of authorities to incidents, accidents or potentially dangerous situations at sea, including search and rescue operations, and contributing to a better prevention and detection of pollution by ships.

Member States shall monitor and take all necessary and appropriate measures to ensure that the masters, operators or agents of ships, as well as shippers or owners of dangerous or polluting goods carried on board such ships, comply with the requirements under this Directive.

"Dangerous goods" means goods classified in the IMDG Code, dangerous liquid substances listed in Chapter 17 of the IBC Code, liquefied gases listed in Chapter 19 of the IGC Code and solids referred to in Appendix B of the BC Code. Also included are goods for the carriage of which appropriate preconditions have been laid down in accordance with paragraph 1.1.3 of the IBC Code or paragraph 1.1.6 of the IGC Code.

"Polluting goods" means oils as defined in Annex I to the MARPOL Convention, noxious liquid substances as defined in Annex II to the MARPOL Convention and harmful substances carried by sea in packaged form as defined in Annex III to the MARPOL Convention.

7.2.4 Places of refuge

"Places of refuge" have been discussed in a workshop held by the European Maritime Safety Agency (EMSA) in March 2004 in Brussels. The identification of these safe havens is fundamental to ensure that ships in distress in EU waters are dealt with more effectively in the future, thereby minimising the effect of maritime disasters.

One of EMSA's main responsibilities is to facilitate the harmonised and effective implementation of the EU's maritime legislation. "Many EU countries have experienced difficulty in implementing the relevant parts of an important ship reporting and monitoring directive (2002/59/EC), which includes plans to accommodate vessels in distress", EMSA's Executive Director Willem de Ruiter said.

The workshop was useful as it allowed for wider consideration of the steps being taken to implement Directive 2002/59/EC; identify and set in place different approaches to places of refuge; organise salvage activities; and deal with associated liability and compensation issues. Member State maritime authorities now have better knowledge of the state of play on the implementation of the Directive and the planning of places of refuge across the EU. This has therefore been a very important step in enabling all Member States to take into account the best ideas and initiatives being planned and implemented in others.

More generally, the discussions highlighted that significant progress has been made on strategic planning for places of refuge in a number of Member states. The next important step will be to make progress on cooperation between countries and, in particular, between those that are close neighbours. EMSA will continue to provide support to these activities. (EMSA, 2005.)

7.2.5 Other EU-related activities

DaGoB (Safe and Reliable Transport Chains of Dangerous Goods in the Baltic Sea Region), funded by the EU's INTERREG IIIB funding mechanism, focuses on dangerous goods transportation in the Baltic Sea area. The main goals of the project are to ensure the effectiveness of the supply chain of dangerous goods, competitiveness and safety. The project plan contains a number of workshops and meetings between the public and the private sector, the aim being to improve co-operation.

There are four working packages in the DaGoB programme:

- WP1, focusing on flows, the supply chain and risks related to dangerous goods
- WP2, co-operation between authorities
- WP3, Action Plan
- WP4, Dissemination and Transfer.

The project tries to combine the best practices of the different authorities and industries in line with the EU's transport policy, safety and security issues and competitiveness of transport chains. The project started in January 2006 and will be terminated in December 2007. The project is coordinated by the Turku School of Economics and Business Administration.

Chemicals are also under study in another EU-funded study entitled "HASREP". HASREP is a pilot study on the response to harmful substances in the EU maritime waters, coordinated by AMRIE (AMRIE, 2005). The project was terminated in the end of 2005, and the results should be distributed in 2006. The main objective of this study is to undertake a pilot study into the nature of chemical substances transported by sea and to gain more knowledge about the response to chemical spills from ships. Thus the essential sub-tasks of this study include monitoring of chemicals in bulk and package form, risk assessment of the transport of harmful substances in EU maritime waters and behaviour of chemical spills at sea. The preliminary results of this report have been presented at the 19th Meeting of Management Committee of Marine Pollution in Brussels, 14–15 November 2005.

A new survey on the transport rates of chemicals in Swedish waters was also started by the Swedish Coast Guard, with the aim of mapping maritime chemical transports in Sweden. The results of the study should be ready for delivery in spring 2006.

Finally, EMSA launched last year an international tender for oil spill response on European waters, focusing on improving response readiness in the Baltic Sea area. This tender led to a solution where five bunkering vessels will be modified to ensure rapid installation of specialised oil pollution response equipment from either the Finnish (Porvoo) or Danish (Copenhagen) stockpiles. The tank capacity of each vessel is over 10,000 m3, and they can operate in difficult weather conditions. Even though this new service contract focuses on the improvement of oil combating, it also increases the operational potential to fight against chemical liquid accidents.

7.3 HELCOM activities

The Helsinki Commission, or HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" – more commonly known as the Helsinki Convention.

To protect the highly sensitive marine environment, the nine Baltic Sea states signed the Helsinki Convention in 1974 and it came into force in 1980. The Convention aims to prevent pollution from ships and land-based sources, as well as from the exploration and exploitation of the seabed and its subsoil. The Convention also regulates the co-operation to respond to marine pollution by oil and other harmful substances. A new Convention was signed in 1992 and it entered into force January 2000.

To protect the marine environment of the Baltic Sea area from pollution, every ship entering the area is urged to comply with the anti-pollution regulations of the Helsinki Convention. In addition to regulations concerning oil, there are regulations concerning noxious liquid substances carried in bulk. (HELCOM, 2004a.)

7.3.1 HELCOM AIS

It is difficult to obtain reliable, up-to-date overviews of shipping traffic in the Baltic. The situation will change, however, when the HELCOM countries complete the installation of the AIS (Automatic Identification System) network around the Baltic, as specified in the HELCOM Copenhagen Declaration. This will allow all the relevant statistics on shipping in the Baltic to be stored in the HELCOM server in Denmark.

HELCOM AIS provides basic data on chemicals based on their classification and amount onboard. The exact names of the chemicals are not given. The current information delivery format of an AIS message does not allow the inclusion of additional data. However, there has been much discussion on the future protocol of the AIS message, and it is quite possible that with the development of modern telematics, the contents of the AIS message can be supplemented with new data, perhaps including the more detailed identification of dangerous goods.

The HELCOM Response Group has defined the basic structure of the HELCOM AIS statistics in the two main cases:

- traffic entering and existing in the Baltic Sea
- regional navigation patterns.

The data presented and stored by the member countries contains statistical information on the ships, dynamic information on the ship position and information related to the direction and voyage such as the draught of the ship and hazardous cargo types. At this very moment research organisations and companies involved in VTS development are working to develop better analysing tools in order to benefit more efficiently from AIS data. New analysing tools will give a better idea of the use of certain fairways, give the statistical distribution of the horizontal space used in certain positions, help VTS operators to monitor the sea area, give an automatic advance warning, include virtual intelligence about the incidents, etc.

7.3.2 Pilotage

Pilotage services are established locally by the coastal states. The need for compulsory pilotage has been discussed several times in connection with the Baltic Sea, and especially with the Danish Straits. IMO recommends that when navigating the Sound loaded chemical tankers and gas carriers irrespective of size should use local pilotage services. HELCOM established a special Expert Working Group (EWG) on Pilotage, the meeting of which in 2004 in Poland resulted in a report on the need and possibility to establish compulsory pilotage within special high risk areas (HELCOM, 2004b).

The Pilot EWG identified a total of ten high-risk areas around the Baltic Sea (Table 20 and Figure 19). The criteria defining an area as high-risk included statistical information about accidents and near-misses, the nature of the sea area including data on water depths, fairway dimensioning, traffic intensity, risk of pollution and the consequences of pollution.

Table 20. High-risk areas around the Baltic Sea identified by HELCOM Pilot EWG (HELCOM, 2004b).

1	Gulf of Finland
2	The Northern and Southern Quark
3	The Southern entrance to the Aaland Sea
4	The Strait of Irbe
5	The area between Bornholm and Sweden
6	The area between the Sound, the Kadetrende, a line from Hammeren to Simrishamn and a line from Bornholm S to Poland at 15° E
7	The Baltic Sea from a line N-S at 11° 57,5' E to a line N-S at 12° 44' E
8	The Baltic Sea W of line N-S at 11° 57,5' E
9	The Sound, the Belts and Kattegat S of a line between Sjaellands Rev and Fornaes
10	Kattegat N of a line between Sjaellands Rev and Fornaes

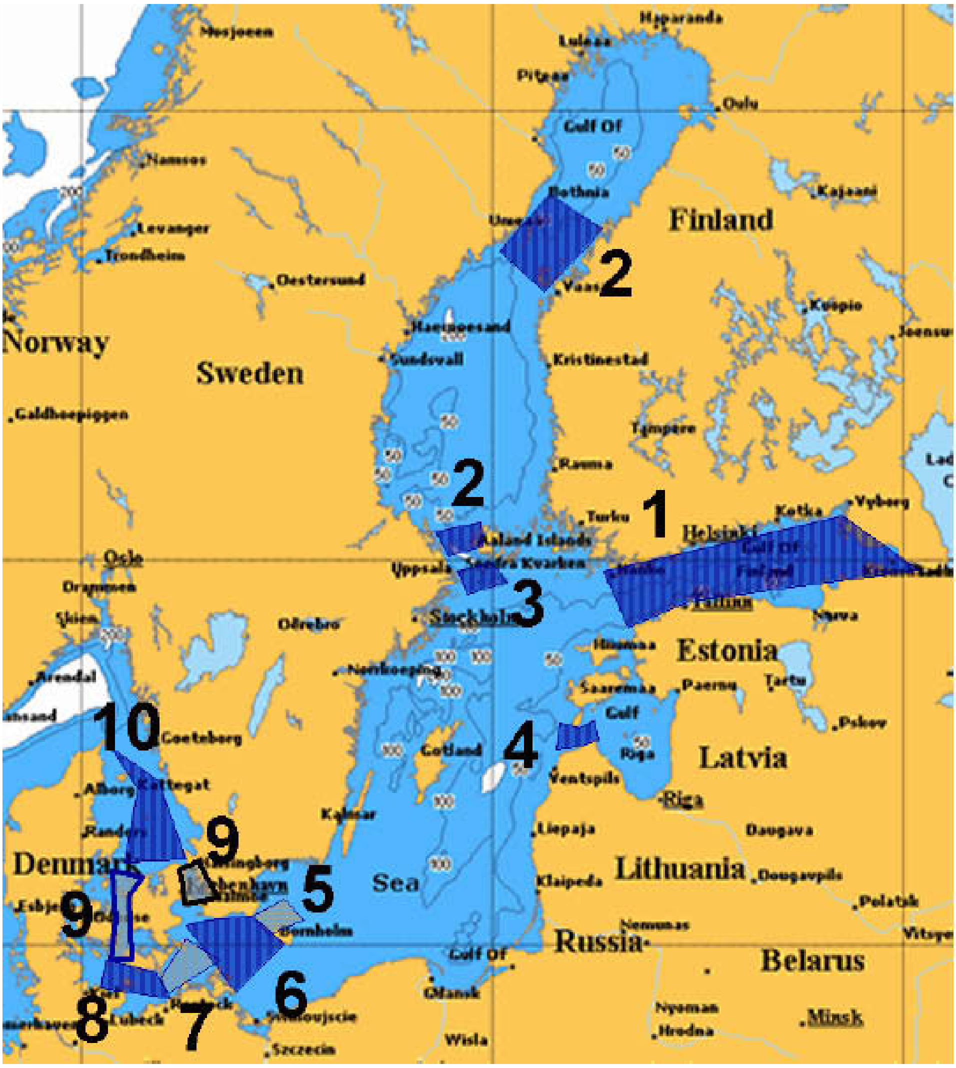

Figure 19. High-risk areas around the Baltic Sea identified by HELCOM Pilot EWG (HELCOM, 2004b).

7.3.3 Escort towing

The need for escort towing on tanker transport routes has been recognised by experts, and a recommendation by HELCOM has been made (HELCOM, 2004c). This has been done to carry out an evaluation on the need for escort services for laden oil and chemical tankers on voyages to and from oil and chemical ports, terminals and off-shore loading places.

HELCOM recommendation 25/5 *Assessment of the need for escort towing in tanker transport routes to prevent accidents in the Baltic Sea area* (HELCOM, 2004c) recommends that the Governments of the Contracting Parties to the Helsinki Convention:

carry out for main tanker transport routes, bound to the main ports/terminals and/or off-shore loading places in their territory or in waters under their jurisdiction before 1 July 2006, an evaluation on the need for escort towing services for laden oil and chemical tankers on voyages to and from oil and chemical ports, terminals and off-shore loading places where a failure of propulsion or steering of a tanker is likely to cause a severe pollution incident due to narrow straits, shallow depths, archipelago areas and/or ice conditions during winter period.

The need for both escort towing and emergency towing capacity with adequate fire fighting devices has been much discussed with experts on maritime safety in the Baltic. At present, there are only a few shipping operators that use escort tug boats, according to the textbook definition of escort. The conventional tug boat used for harbour manoeuvres is not capable of escorting or emergency towing. Escort tug boats have more power and better rudder arrangements than conventional tugs, and so can maintain assistance even in difficult weather and at a higher speed. An escort tug can offer first aid to the tanker and prevent it from going onshore in the case of a black-out situation.

Experts have also recommended additional safety measures for tankers: they can be fitted with emergency tow packages that can easily be deployed to a tug in the event of power or rudder failure (Steiner, 2004). These should consist of adequate tow wire and pick-up line and buoy.

7.3.4 HELCOM Response Manual – Volume 2

The International Maritime Organization (IMO) estimates that more than half of the packaged goods and bulk cargoes transported by sea today can be regarded as dangerous, hazardous or harmful to the environment. A great deal of these substances is also dangerous or hazardous to humans. Accidents and spills involving chemicals, as well as lost packages of dangerous goods, must be reported to all the relevant bodies according to national and international agreements and regulations.

Definition of response

The efforts to minimise the risks created in an emergency by protecting the people, the environment, and property, and the efforts to return the scene to normal pre-emergency conditions.

The HELCOM Response Group works to ensure a swift national and international response to maritime pollution incidents. The response group co-ordinates the aerial surveillance of maritime shipping routes to provide a complete picture of sea-based pollution around the Baltic and to help identify suspected polluters. The Group also continuously updates and reviews the HELCOM Response Manuals: Volume 1 (Oil) and Volume 2 (Chemicals). Here is presented a short summary of Volume 2.

The aim of the HELCOM Response Manuals is to provide information to support proper decisions when responding to accidents in the marine environment involving chemicals and dangerous goods. The manual focuses on spills and lost packages. The following issues are handled: spill behaviour, drift forecasting, monitoring, sampling and response. The annexes describe first response, resistivity of materials, case histories, classification of spills, body protection and labelling.

Annex 3 of the HELCOM Response Manual, Volume 2, contains selected case histories of marine chemical accidents. The list contains 34 cases, 8 of which occurred in the Baltic Sea region. The cargo onboard in these 8 cases contained fertilizers, hydrochloric acid, phenol, sodium chlorate, propionic acid, ammonia and chromium dioxide. In most cases the chemicals were in drums or cisterns, and the main cause of the chemical accident was related to loading or unloading. One case was related to loss of deck cargo (drums), one to grounding and one to collision. In two of these cases there was a fire and gas plume formation with loss of human lives. Some of the chemicals were also overheated due to contact with oxygen (when released out), thus increasing the danger of explosion and initiating a fire. The list of case histories underlines the necessity to know well the transported chemicals onboard in the case of accidents and when considering the appropriate response actions.

The HELCOM Chemical Response Manual (HELCOM, 2002) also gives a basic overview of the existing methods and methodologies for predicting the drift and spreading characteristics of chemical spills. Forecasting rules have been presented for gas clouds, floating spills, dissolved spills and sinking chemicals.

Some forecasting models have also been presented, such as:

- ALOHA for the prediction of gas behaviour due to accidental release
- MET for the prediction of toxic effects and risk of human injuries due to the gas plume
- CHEMMAP for the prediction of the dispersion and fate of marine chemical spills
- ChemSIS for the prediction of the dispersion and fate of marine chemical spills
- 3D Transport & Water quality Model for dissolvers and sinkers.

A more detailed description is given in (HELCOM, 2002). It should be noted here, however, that there are several more numerical models available for the estimation of the behaviour and fate of different chemical spills.

7.3.5 Co-operation in case of a chemical tanker accident

HELCOM recommendation 12/7 *Special cooperation in case of a chemical tanker accident in the Baltic Sea* (HELCOM, 1991) recommends that the Governments of the Contracting Parties to the Helsinki Convention:

a) nominate a contact point through which competent authorities of other Contracting Parties can, in emergency situations, without delay get information on the chemicals carried by a tanker from or to a harbour of a Party concerned *b) by national measures create as soon as possible but not later than by the end of 1992 an information system which would, in case of a chemical spillage, facilitate access by the competent authorities to data concerning the chemicals carried by the tankers*

c) provide, in accordance with Regulation 8 of Annex VI to the Convention, and within their ability, other Parties with special assistance like experts to respond to chemical spillages, special protective clothing and equipment for combating personnel, and special instruments for chemical analyses.

Recommends also *that the Governments of the Contracting Parties inform each other of their national facilities where chemical wastes emanating from combating operations can be treated and disposed of and make all efforts to provide necessary waste treatment possibilities after an accident has occurred off the coast of another Contracting Party.*

8. Discussion

The liquid bulk form chemical transport rate in 1987 was estimated to be 5.8 million tons. The volume of gas transportations was 2.9 million tons. When updating the liquid bulk chemical transport rates many statistical uncertainties existed: some data received contained all chemicals transported, and it was difficult to separate liquid bulk transports. There were also ports and operators that did not give realistic data even if there were indications of chemical transport.

The difficulty in obtaining valid data for this publication is a result of the fairly heavy market competition, meaning that chemical manufacturers and operators are not willing to give data. Some of the chemical industrial sites are located close to ports or terminals, and so port data might contain data concerning a specific industrial plant. For some terminals it seemed that the data was classified as an industrial secret.

Based on the data received, liquid bulk chemical transport in the Baltic Sea was around 9.1 million tons in 2004. Due to the inaccuracies in the reports and data received, it may be assumed that the realistic figure is slightly higher. The inaccuracies are based on non-harmonised reporting of the data and sometimes on the lack of data. When analysing the data of Chapter 5, it can be noted that there is a need for a harmonised method to collect and gather data. Often the chemical transport rates included also other bulk form chemicals, fertilizers, etc. According to the Russian Baltic Sea data chemical transports exceeded 5.1 million tons, but the figure for liquid form chemicals was roughly 50,000 tons. The Swedish port of Gothenburg likewise reported hardly any chemical liquid bulk transports even though there are several chemical plants close to the port. The numbers received from the Baltic countries might also be slightly higher, but again, the obvious reason for the unclear data seems to be the lack of harmonised reporting and collecting of data.

At present it seems that new terminals and industrial sites will be built in the Baltic Sea area, and this will lead to a rapid local increase in the amount of chemicals transported. Poland, the Baltic countries and Russia are building more capacity for terminals and also for chemical transport. However, due to globalisation, it may be that some of the existing main routes for chemicals from industrial sites to markets will be terminated, and new logistically advantageous routes will be established. Here again it is likely that the focus will be directed more to Russia, Poland and the Baltic countries.

The chemical transport figure in Finland grew around 20% during the last decade. A comparison of the data for 1987 and 2004 shows an overall growth of 100% over 17 years. Thus, taking into account the positive development of maritime transport and GDP especially in Poland and the Baltic countries, transport in chemical liquid bulk form may exceed 15 million tons by 2015. However, if the new biofuels are placed on the market earlier than expected (crude oil price goes even higher, new strict legislation to reduce NO_x's), bulk form chemical transport rates may increase exponentially.

Chemical carriers are usually very sophisticated ships having strict standards for safety and security. However, the cargoes they carry often present tremendous challenges and difficulties from a safety point of view, and many chemicals are a far greater pollution threat than for example crude oil. According to the Lloyds Register Fairplay, there were 1,339 tankers in use in 2004 as well as 1,666 chemical/oil tankers. The world tanker tonnage, including oil, products, chemicals, LNG, had a share of 41.3 percent of the world total merchant fleet with a capacity of 368.4 million dwt. Chemical/product tankers had an average Gross Tonnage, GT, of 12,436 tons, and an average age of 11.83 years. Average length, breadth and draught were 135.4 m, 21.82 m and 8.6 m, respectively.

The most common chemicals transported in the Baltic were ammonia, acetone, ethylene, glycol, phenol, phosphoric acid, methanol, sulphuric acid, styrene monomer and caustic soda. There were 43 enterprises in 2004 in the Baltic area (including Norway) that own or operate chemical tankers. These companies had about 500 chemical tankers and oil product/chemical tankers altogether.

When assessing the possible risk of pollution due to the accidents of chemical tankers, the following scenarios can be presented:

1. The casualty happens in open sea conditions.

2. The casualty takes place close to the coastline, or close to sensitive areas such as archipelagos.

3. The casualty takes place in a closed area such as a harbour or terminal area.

4. The casualty takes place during the winter time in the presence of ice and snow.

– Open sea conditions (1.) usually characterise conditions where the spill has more time to spread, dissolve or vaporise. It will also take more time for response units to reach the accident site and to undertake protective measures, such as booming, lightening operations and recovery works. The open sea area is also more sensitive to wind and waves, and in rough conditions there are technically very limited possibilities to work sufficiently close to the damaged ship to control the situation.

However, if the spilled chemical has the tendency to evaporate or dissolve, it will mix with the larger water masses more rapidly and thus have a less fatal impact on the environment. In certain cases, large amounts of chemical mixed with the sea water will increase the chronic toxic level before the concentration level due to the accident has reached the background level once more. In open sea conditions, the most critical factor is the time needed to get to the site and start to prevent leakage into the surrounding environment.

– Coastline and archipelago conditions (2.) usually give two scenarios for controllability: first the surrounding islands and the coastline offer a place of refuge where the damaged ship can be towed or where booming measures can be taken successfully. However, these environmental conditions also pose an increased environmental risk of pollution: the coastline and archipelago environment is a habitat for marine organisms, fish, waterfowl and seals and is also the site of human activities.

Thus if the chemical spill has the time to spread widely, the consequences would be significantly larger than in open sea conditions. It is a well known fact in European conditions that the recovery costs for the enlightening operations: recovery in open water: beach cleaning activities are 1:10:> 100. The impact evaluation may be even more severe, such as 1:10:> 1 000.

– The casualties in harbour or terminal area (3.) can usually be restricted by the port and terminal personnel. Usually the spill site can be effectively localised, on condition of course that the detection has been made in time and the recovery actions have been started in a proper manner. In the case of chemicals dissolving in the water mass, however, large-scale spillage can cause severe local acute toxicity, which will cause the total loss of marine organisms in the accident site.

– Winter conditions (4.) characterise chemical spills in the northern part of the Baltic Sea. The dominant factors here are the low temperature and the presence of ice and snow. The cold environment changes significantly the viscosities of the chemicals, thus affecting the recovery efficiency of a large set of mechanical units. The surrounding ice and snow will also make it difficult for the recovery fleet to operate. The detection of chemicals is also difficult, and if the chemicals go under the ice, in practice only limited operations can be performed in the accident site.

During the years 1989–2003, only three chemical accidents were reported to HELCOM. Annually there are roughly 50–60 collision and grounding accidents of ships in the Baltic, and it is assumed that the figure may increase due to the rapid development of maritime transport. However in spite of this development, the risks will not increase linearly with the increasing number of calls or shipments. A set of new risk handling options have been established to improve maritime safety, and many new tools are still in the development and testing phase. The policy of phasing out single hull tankers is one of the most recent decisions of the maritime community. Stricter legislation, port state control and actions to establish waste reception facilities have all improved the transportation culture: during the past three decades the number of larger-scale oil spills has decreased dramatically (ITOPF Web page). The previous figure of 34...35 annually reported oil spills with a magnitude of over 700 tons has dropped to 3...4 spills annually in recent years. The same tendency will continue due to the new IMO and EU regulations, and thanks to the new tools to improve safety.

In the Baltic Sea area one of the most effective tools to improve safety has been cooperation with HELCOM and the drafting of a large set of recommendations. After the oil accidents of MT Baltic Carrier in 2001, several working groups were established to improve piloting, ice navigation, surveying, routeing, AIS development, etc. Now HELCOM AIS is already in operation, new routing measures have been adopted by IMO in the Baltic Sea and soon all the main shipping channels will have been surveyed accurately, enabling the use of Electronic Seacharts (ECDIS). VTS services have been established by many countries, and the Gulf of Finland mandatory reporting system, GOFREP, launched trilateral co-operation already in 2004.

When trying to evaluate the risk of a chemical spill in the Baltic area, a study such as the Formal Safety Analyses should be carried out, where all the effects and local environmental priorities are taken into account properly. However, when trying to evaluate the expected tanker spill site a more accurate estimation can be made. Based on IMO's regulations, the total mean outflow in an accidental situation will give roughly 2,500 m^3 and 4,500 m^3 spills for tankers of 40,000 and 71,000 dwt, respectively. For new tankers (Regulation 13G) the corresponding outflow rates are roughly 1,500 and 3,500 m^3 (total outflow). In extreme situations the IMO rule will give roughly 6,000 and 12,000 m^3 spills.

These figures can be used for oil tankers, but for chemical tankers they may give too large values because of the larger number of cargo compartments. Thus the method of (Herbert, 1998) would be more reliable for chemical carriers; they give for 5,000 dwt tankers a spill range of 50–112 tons of chemicals depending on the compartment arrangements and the damage location (side damage, bottom damage). For this vessel class, the mean outflow parameter varies between 0.009–0.015.

For a 40,000 dwt tanker, the expected side or bottom outflow in the damage is in the order of 400–900 tons, depending on the conditions explained above. The mean outflow parameter varies in the range of 0.011–0.13. Thus for the most common size of the chemical tankers used in the Baltic Sea, i.e. for the range of 5,000–10,000 dwt, the mean outflow rate is in the order of 50–200 tons depending on the accident conditions.

The estimations above show clearly that the expected chemical outflow will vary greatly depending on the case. Much depends on the ship characteristics as well as on the environmental parameters and local conditions. Moreover, a chemical spill may have a totally different nature than an oil spill due to the basic behaviour of the transported chemicals. Five main groups of chemicals can be identified based on their behaviour when spilled out: floaters, sinkers, evaporators, mixers and suspensions. The selection of an appropriate control method thus requires correct data on the chemicals.

Due to the fact that some chemicals may heat when in touch with water, the risk of explosion and fire always exists. Poisonous gas formations may also make it difficult for the ship crew to control the spill in the initial phase.

Finally, a large number of chemical tankers sail in ice-infested waters. Based on a report covering the period 1975–2000, winter navigation in the northern Baltic Sea poses a rather small risk to shipping. The average frequency of ice damage, incidents or accidents is significant, but consequences are rather slight. Most of the accidents and incidents related to ice have minor consequences, and very rarely do any spills take place due to this damage.

The total risk of winter navigation (all merchant ships) can be divided into three main categories, i.e., the risk for people, for the environment and for property. During a normal winter an outflow is expected to take place once in 2–5 years, while during a severe winter pollution accidents can be expected to take place yearly. This estimation, however, does not focus on chemical tankers alone, but also shows the impact of ice navigation on the merchant fleet.

Based on the analyses above it seems evident, that the risks of chemical transportation along the Baltic Sea is smaller compared to much larger volumes of oil transportation. However, the risk for unwanted accidents always exists, as was realised when finalising this publication for printing: a chemical tanker collided in the English Channel and sank down with 10,000 tons of phosphorous acid. There were also some minor bunker oil releases on-site.

The English Channel is one of the busiest sea routes of the world resulting higher amount of near-miss situations and accidents. Even with the modern navigation aids and electronic systems onboard nasty failures and mistakes happen. When looking forward the all available means to identify risks, to find optimum risk handling options and to improve the maritime safety, one must realise that 80% of all the mistakes, near-misses and accidents are human-related. Thus, even if a lot of technical improvements whatsoever will be taken care with that remaining part of 20% the total risk for damages, losses of lives and pollution will not decrease a lot.

The maritime industry is developing rapidly and the maritime business is meeting severe competition and the hard facts of business life. Crews onboard are coping with long shifts, crowded sea areas, various cultures onboard, different technological solutions onboard, electronical failures, software problems etc. There are endless list of possible causes for human errors leading to near-miss situations. Some of these situations will be developed to accidents. Even if there are sophisticated tools available everything can go wrong.

Thus the previous case of the sunken chemical tanker "ECE" in the English Channel with the 10,000 tons of chemicals onboard should be taken as a classical example of the collision, which may also take place in the Baltic Sea area, regardless of the good conditions of the chemical tankers sailing in the Baltic, trained crew onboard and regardless of the modern technology onboard or onshore (VTS, AIS, ECDIS, PILOTAGE etc.). Likewise the English Channel, Baltic Sea is also one of the crowded sea routes in Europe and even more vulnerable for a large scale chemical or oil spill. The shipping is one the safest transportation modes in the world. The superior economics for transporting bulk cargo makes it also vulnerable for large scale accidents.

9. Recommendations

The main objective of this work has been to collect data on liquid bulk chemical transportation in the Baltic Sea area. Thus the vital element of the work was to collect data on chemicals and transported volumes. However, it quickly became clear that obtaining data requires a lot of work, inquiries and contacts. There was no joint data bank for this purpose, and in order to understand the situation, the validity of the data should be checked and cross-checked.

Different bodies collect and document chemical transport data in various ways. The concept "chemical" has different meanings for different parties. Some parties had business activities related to chemical transport and the loading or unloading of chemicals, but for some reason, it was difficult to receive data for research purposes. The chemical transport sector faces much competition, and so companies keep as much data as possible confidential. However, if relevant data is not easily at hand, the uncertainties related to the chemical's behaviour in an incident situation may hinder salvage and combating actions.

The rate of chemicals transports is much lower than the rate of oil transports, and the probability of a severe accident and environmental pollution is smaller as well. However, risk determination in the Baltic Sea area requires a harmonised approach to identify the risks and find optimal risk handling options. A Formal Safety Analysis approach should be made for the whole Baltic Sea area, covering all the modes of sea transportations, cargoes and local possibilities to improve safety, i.e., to decrease the risk of incidents.

New telematic tools have recently been or will be established to improve maritime safety in the future. Many countries have already set up their local VTS services. HELCOM AIS started in summer 2005 and will significantly improve the rapid and reliable monitoring of traffic. It will also enable a new dimension for ship-to-ship and ship-to-shore communication. AIS data, however, do not yet give any indication of the quality of the tanker's cargo; this would be important information in emergency situations. The current AIS protocol does not make it possible to include this information, but telematics and ICT are developing rapidly, and perhaps new-generation systems will be of help as well. SafeSeaNet co-operation may also offer improvements.

Even though there is a great deal of information on the possible impacts and fate of chemicals in aquatic conditions, it is also clear that this data is usually based on micro-scale laboratory testing in ideal conditions. A larger-scale spill may be impacted by wave dynamics, ice and snow, and cold and warm conditions, meaning that the behaviour and impact level as well as the appropriate countermeasure selected may vary greatly. Sophisticated modelling work would predict the possible impacts and spreading velocities better. It is evident that new protocols should also be created for the brackish water conditions of the Baltic Sea. It is likely that some of the older analysing methods do not detect properly the possible environmental impacts (cf. the development of detection and measuring protocols of TBT).

Chemical accidents do not necessarily cause as serious environmental impacts as oil accidents. One of the reasons, of course, is that lesser quantities of chemicals than of oil are transported, and thus lesser quantities of chemicals are spilled in accident situations. Chemical tankers also have several small tank compartments, thus a possible spill volume is usually smaller than from an oil tanker. The accident reports also support the observation that in many cases the released amount of chemicals is not large enough to lead to any significant damage. The most serious impacts are usually due to an explosion, gas formation or fire onboard causing the loss of human lives and injuries. Cases where human lives have been lost highlight the need for harmonised information on transported chemicals for the whole logistics chain. Another recommendation would be to improve training of the crew in an emergency situation in order to avoid human losses. The development of a fast and reliable portable analysis tool for the outflowed chemical/gas plume is essential to the salvage operation.

The behaviour of chemical spills in winter conditions should also be studied more thoroughly, and recommendations should be given for appropriate countermeasures. It is rather evident that the amount of liquid bulk chemical transports will not increase with the same intensity as oil transportation in the Baltic Sea. However there are two main trends. Firstly, new terminals will be constructed and some of the older terminals will be widened. One reason for this is the optimisation of the whole logistic transport chain as a result of globalisation. The second trend will be seen with the rapid growth of new biofuels for cars and industry. The biofuels should be taken into account already now when preparing long-term response manuals or making decisions on new recovery and combating technology.

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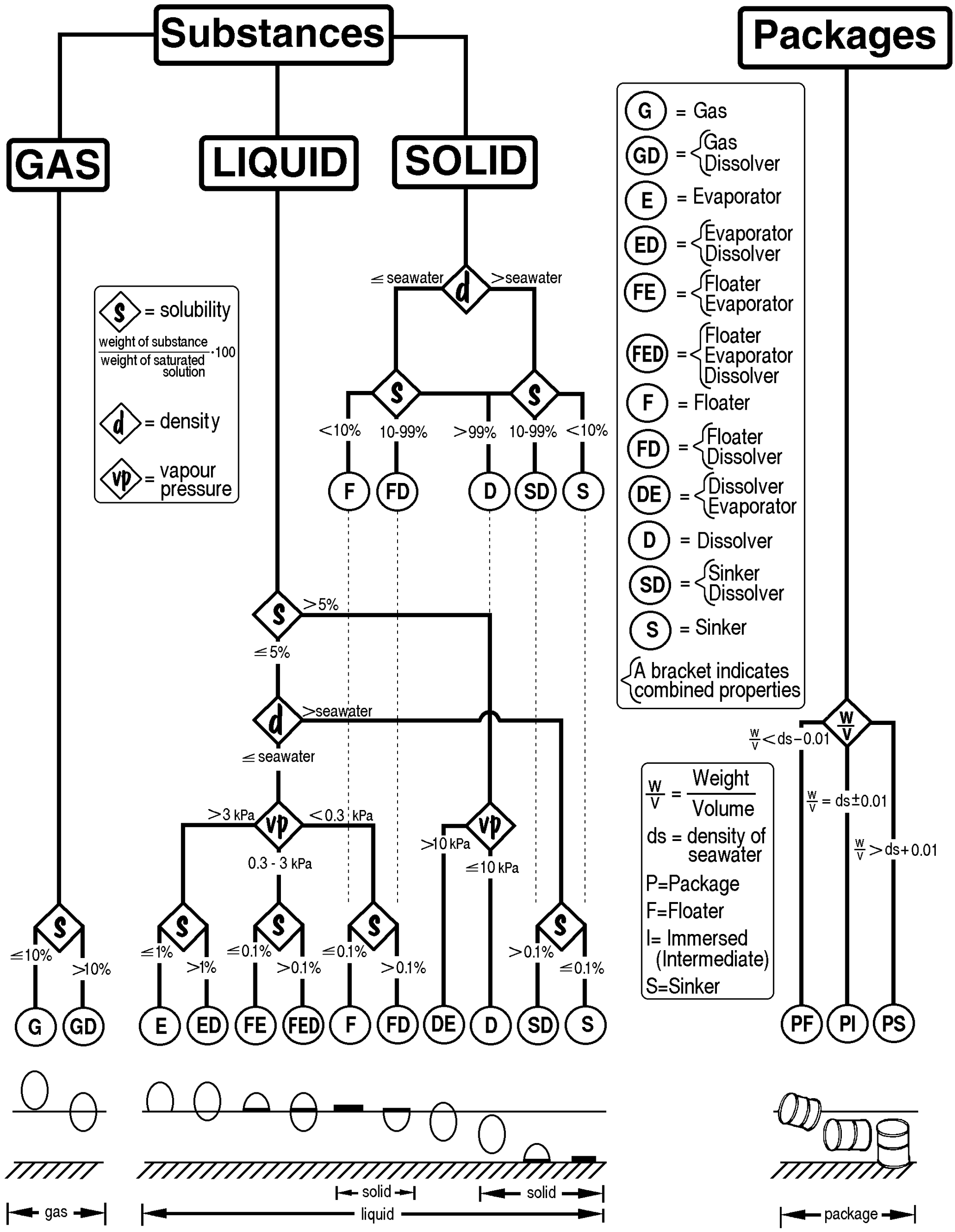
Appendix A: The 12 property groups of chemicals with behaviour descriptions

	Group Designation Meaning of Designation	Properties	Examples	SPREAD A = air WS = water surface WB = water body B = bottom
Evaporate immediately	G gas	evaporate immediately	propane, butane, vinyl chloride	A
	GD gas/dissolver	evaporate immediately, dissolve	ammonia	A WB
Evaporate rapidly	E evaporator	float, evaporate rapidly	benzene, hexane, cyclohexane	A
	ED evaporator/ dissolver	evaporate rapidly, dissolve	methyl-t-butyl ether, vinyl acetate	A WB
Float	FE floater/ evaporator	float, evaporate	heptane, turpentine, toluene, xylenes	A WS
	FED floater/ evaporator/ dissolver	float, evaporate, dissolve	butyl acetate, isobutanol, ethyl acrylate	A WS WB
	F floater	float	phthalates, vegetable oils, animal oils, dipentene, isodecanol	WS
	FD floater/ dissolver	float, dissolve	butanol, butyl acrylate	WS WB

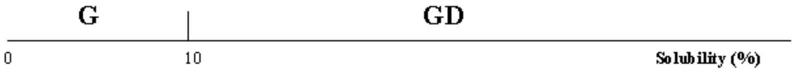
Dissolve	DE dissolver/ evaporator	dissolve rapidly, evaporate	acetone, monoethyl amine, propylene oxide	A WB
	D dissolver	dissolve rapidly	some acids and bases, some alcohols, glycols, some amines, methyl ethyl ketone	WB
Sink	SD sinker/ dissolver	sink, dissolve	dichloromethane, 1,2-dichloroethane	WB B
	S sinker	sink	butyl benzyl phthalate, chlorobenzene, creosote, coal tar, tetra ethyl lead, tetra methyl lead	B

(Bonn Agreement, 2000)

Appendix B: Flow diagrams (Bonn Agreement, 2000)

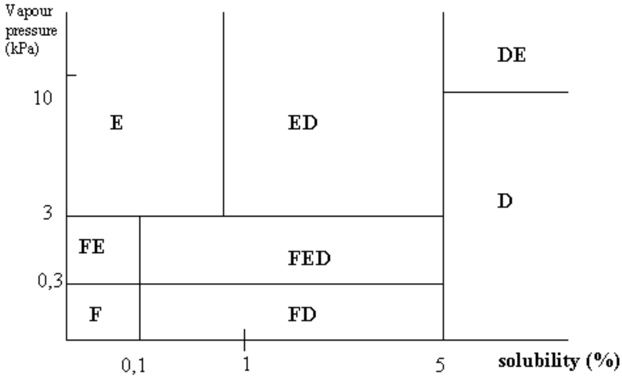


GAS

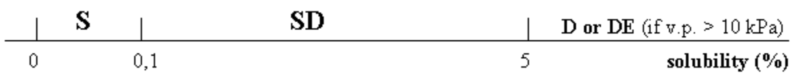


LIQUIDS

***Floating liquids*: d ≤seawater**

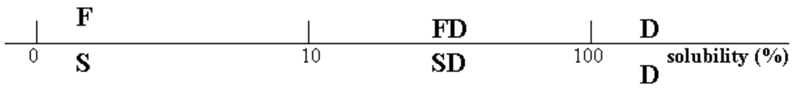


***Sinking liquids*: d > seawater**



SOLIDS

***Floating solids*: d ≤seawater**



***Sinking solids*: d > seawater**

Appendix C: Overview of response methods

A basis for adequate response to chemical spillage classified in 12 groups.

The table is applicable for methods against HNS releases only								**Solid Subst**			**Solid Subst**		
								F	**FD**		**D**	**SD**	**S**
		GAS		**L I Q U I D**									
METHOD	**GROUP**	**G**	**GD**	**E**	**ED**	**FE**	**FED**	**F**	**FD**	**DE**	**D**	**SD**	**S**
	FORECASTING												
F1	Forecasting the spread in air	**X**	**X**	**X**	**X**	**X**	**X**			**X**			
F2	Forecasting the spread on water surface					**X**	**X**	**X**	**X**				
F3	Forecasting the spread in water body		**X**		**X**		**X**		**X**	**X**	**X**	**X**	
	MONITORING												
M1	Monitoring the spread in air	**X**	**X**	**X**	**X**	**X**	**X**			**X**			
M2	Monitoring the spread in water body		**X**		**X**		**X**		**X**	**X**	**X**	**X**	**1)**
	COMBATING METHODS												

C1	Combating water soluble gas clouds		**X**										
C2	Combating spills that float on water							**X**					
C3	Combating spills that dissolve in water		**X**		**X**		**X**		**X**	**X**	**X**	**X**	
C4	Combating spills that sink to the bottom											**X**	**X**
	[1] *It may also be appropriate to monitor sinkers that move over bottom in the water body*												

(Bonn Agreement, 2000)

Selection of combating methods. The table below gives an indication of possible combating methods applicable for the groups GD, F, D, SD and S.

GROUP	PROPERTIES	EXAMPLES	COMBATING METHODS (examples)	
G	evaporate immediately	butane, vinyl chloride	–	–
GD	evaporate immediately significant solubility in water	ammonia	C1	"knock down" vapour clouds with water fog for ammonia see also method C3
E	evaporate rapidly	benzene, hexane, cyclohexane	–	–
ED	evaporate rapidly significant solubility in water	acrylonitrile, n-butylaldehyde, ethyl acetate, methyl t-butyl, ether, vinyl acetate	–	–
FE	float, evaporate	heptane, toluene, turpentine, xylenes	–	–
FED	float, evaporate, dissolve	n-butyl, acetate-ethyl acrilate	–	–
F (and Fp)	float	phtalates, fatty oils, ethylexyl alcohol, styrene, nonene	C2	mixing with special treating agents and/or recovery by skimmers
FD	float, dissolve	n-butanol, butyl acrylate	–	–
DE	dissolve rapidly, evaporate	acetone, monoethyl, amine, propylene oxide	–	–
D	dissolve rapidly	some acids and bases, some alcohols, glycols, acetone	C3	acids could be neutralized with sodium bicarbonate;

		cyanohydrin, methyl ethyl ketone		bases could be neutralized with sodium dihydrogen phosphate
SD	sink, dissolve	aniline, carbon disulphide dichlormethane 1,2-dichloroethane	C4	recovery from seabed with dredging systems (e.g. airlift or peripheral injector jet pipe)
S	sink	butyl benzyl phthalate, chlorobenzene, coal tar, coal tar oil creosote, phtalic anhydride, tetraethyl lead	C4	recovery from seabed with dredging systems (e.g. airlift or peripheral injector jet pipe)

Method C1 – Combating water soluble gas release
Method C2 – Combating spills of floaters on the sea
Method C3 – Combating dissolved spills in the water column
Method C4 – Combating spills of sinkers on the seabed

Methods C1–C4 are described in detail in the HELCOM Manual on Cooperation in Combating Marine Pollution in the Marine Environment in the Baltic Sea Area, Vol III – Response to Chemical Spills from Tankers, January 1990, in the REMPEC manual "Practical Guide for Marine Chemical Spills", 1999, and in the re-edited version of IMO's manual on Chemical pollution – Section 1: Problem Assessment Response Arrangements.

(Bonn Agreement, 2000)

Appendix D: Tanker owners and operators in the Baltic (incl. Norway)

Company	Country
BR Shipmanagement	DENMARK
Copenhagen Tankers	DENMARK
D/S Norden	DENMARK
Dannebrog Rederi	DENMARK
Eitzen Chemical	DENMARK
Herning Shipping	DENMARK
Jens Jakobsen	DENMARK
Nordtank Shipping	DENMARK
TESMA	DENMARK
Transmarine Management	DENMARK
Wonsild & Son	DENMARK
Crystal Pool	FINLAND
Neste Oil Shipping	FINLAND
Chemikalien Seetransport	GERMANY
Ernst Jacob	GERMANY
Fisser & Doornum	GERMANY
German Tanker Shipping	GERMANY
Carl Büttner	GERMANY
John T Essberger	GERMANY
Rigel Schiffahrts	GERMANY
Schoeller Holdings	GERMANY
Tankreederei Ahrenkiel	GERMANY
Latvian Shipping	LATVIA
Anders Utkilens	NORWAY
Bryggen Shipping & Trading	NORWAY
Halfdan Ditlev-Simonsen	NORWAY
Iver Ships	NORWAY
Jo Tankers	NORWAY
Knutsen OAS	NORWAY
Odfjell Tankers	NORWAY
Seatrans	NORWAY
Vista Ship Management	NORWAY
Novoship	RUSSIAN FEDERATION
Primorsk Shipping	RUSSIAN FEDERATION
Sovchart	RUSSIAN FEDERATION
Brostrom	SWEDEN
Donsötank	SWEDEN
Ektank	SWEDEN

Furetank Rederi	SWEDEN
Laurin Maritime	SWEDEN
Sinbad Chartering	SWEDEN
Tarbit Shipping	SWEDEN
Tarntank Rederi	SWEDEN

Appendix E: Chemicals transported through Finnish ports in 1994 (VTT, 1995)

	Kemikaali	MARPOL-luokka	Pääluokka	Kuljetusmäärä [tonnia]
1	methanol	non-pollutant	FD	742410
2	sodium hydroxide solution	D	SD	396298
3	Be 92 & 99 & 95E	C	FE	283036
4	orthoxylene	D	FE	226565
5	ammonia aqueous	C	FD	213338
6	phosphoric acid	D	SD	183351
7	paraxylene	C	FE	172742
8	styrene monomer	B	FE	136316
9	benzene	C	FE	108168
10	acetone	non-pollutant	FD	104526
11	phenol	B	FD	94446
12	monoethylenglycol	D	SD	93303
13	ethanol	non-pollutant	D	87166
14	synthetic ethanol	non-pollutant	D	78767
15	styrene	B	FE	75000
16	benzene/toluene/xylene mixtures	C	FE	57171
17	n-paraffin	D	FE	48794
18	tall oil	B	F	48738
19	n-butanol	non-pollutant	FD	46454
20	sulphuric acid	C	SD	45400
21	isopropylbenzene (cumene)	B	FE	44816
22	propylene trimer	B	F	42500
23	fluosilicic acid	C	SD	34284
24	ethyl acetate	D	F(D)(E)	29672
25	C2/C9 fractions	C	FE	28696
26	coal tar	A	F(E)	27500
27	ethyl alcohol	non-pollutant	FD	27479
28	nitric acid	C	SD	26912
29	magnesium sulphonate	C	S	24848
30	isobutanol	non-pollutant	FD	22005
31	glycol	non-pollutant	SD	15877
32	cyclohexanone	D	F(D)(E)	14772
33	vinyl acetate	C	F(E)	14326
34	tall oil fatty acid	C	F	13519
35	alpha methyl styrene	A	FE	12245
36	trichloroethylene	B	S(E)	11867
37	aniline oil	C	S	11450
38	butyl acetate	C	FD(E)	11324

	Kemikaali	MARPOL-luokka	Pääluokka	Kuljetusmäärä [tonnia]
39	dichloromethane (methylene chloride)	D	S(E)	9985
40	ethylene dichloride	B	S(E)	8645
41	turpentine	B	FE	7805
42	nonyphenol ethoxylate	B	D	6592
43	alkyl benzene	D	FE	6567
44	toluene	C	FE	6480
45	acetic acid	D	SD	6470
46	isopropyl alcohol (IPA)	non-pollutant	FD	6170
47	monoammonium phosphate	non-pollutant	SD	5672
48	butyl acrylate	B	FD(E)	5624
49	pyrolysis gasoline	C	FE	5494
50	calcium ammonium nitrate	D	SD	4989
51	monoammonium sulphate	D	SD	4898
52	acetic anhydride	C	SD	4882
53	methyl tert butyl ether	D	FE	4372
54	white spirit	B	FE	3790
55	monochlorbenzene	B	S(E)	3441
56	ethylene glycol monoethyl ether	non-pollutant	SD	3318
57	cyclohexane	C	FE	3037
58	hexan fraction C	C	FE	2682
59	ethyl glycol, ethylene glycol	D	SD	2446
60	xylene	C	FE	2397
61	sodiumborohydride (Borol)	C	S*	2042
62	potassium hydroxide solution	C	DS	2030
63	chlorobenzene	B	S(E)	1903
64	glycerine	non-pollutant	SD	1739
65	formic acid	D	SD	1700
66	dioctylphtalate	non-pollutant	S	1683
67	dimethylformamide	D	(F)D	1611
68	monopropylene glycol	non-pollutant	S*D	1587
69	alphamethylstyrene fr.	A	FE	1555
70	ethyl glycol ether	D	(F)D	1276
71	Glyoxal 40	D	SD	1200
72	1,3-pentadiene (piperylene)	C	FE	1017
73	1,1,1-trichloromethane (methylchloroform)	B	S(E)	979
74	perchloroethylene	B	S(E)	951
75	hydrocarbon solvent (Solvent K)	non-pollutant	FE	876
76	carbon tetra chloride	B	S(E)	780
77	C8/C10 fatty alcohols	C	FD	515
78	ethanol ethyl acetate	D	F(D)(E)	504
79	coal tar naphta solvent	B	FE	470
80	MPG	non-pollutant	SD	397
81	methyl metacr. monomer	D	FE	300
82	methyl ethyl ketone	D	FD(E)	270
83	ethyl hexyl acrylate monomer	B	F(E)	120

* uppoaa makeassa ja murtovedessä, voi kellua suolaisessa vedessä

	Kaasu	Kuljetusmäärä [tonnia]
1	Pygas	256523
2	butane	74429
3	propane	36000
4	gascondensate	20816

Note:

Pygas (pyrolysis gasoline) is not a gas but a liquid. Pygas is a naphtha-range product with a high aromatic content, used either for gasoline blending or as a feedstock for a BTX (benzene, toluene and xylenes) extraction unit. Pygas is produced in an ethylene plant that processes butane, naphtha or gasoil.

Appendix F: The questionnaire sent to ports

Subject: Chemicals transported in liquid bulk

Recipients: Ports that handle chemicals in liquid bulk in the Baltic Sea area

VTT is doing a study called “Transportation of chemicals by tankers in the Baltic Sea area”, funded by the Finnish Ministry of the Environment, Finnish Maritime Administration and Finnish Environment Institute. The objective is to update the 15-year old HELCOM report “Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area”. We have conducted discussions with Mr Thomas Fagö, Chair of the HELCOM Response group, and he supported the idea of updating the information on Baltic chemical transport.

The idea is to find out the main chemical shipping routes, list the most common chemicals and then to make a brief review of the possible risks related to chemical transportation in the area. I am now gathering statistics from those Baltic ports where chemicals in liquid bulk are handled. Even if you do not handle liquid chemicals, please reply anyway so that I can update my port list.

I would appreciate it if you could provide me with the following information from the year 2004:

- chemicals handled in liquid bulk in tons (total and/or import and export separately)
- the ten most common chemicals and their volume in tons (if possible, please give the MARPOL class of each chemical)
- the number of chemical tankers calling your port in 2004
- the most important destinations / ports of departure (a good “guesstimate” is enough).

The complete report will be sent to all the ports we get statistics from.

This inquiry was sent to the following ports:

Finland:

- Hamina
- Kotka
- Sköldvik
- Helsinki
- Inkoo
- Hanko
- Turku
- Naantali
- Uusikaupunki
- Rauma
- Pori
- Kaskinen
- Pietarsaari
- Kokkola
- Rautaruukki
- Oulu
- Kemi
- Tornio

Sweden:

- Stenungsund
- Örnsköldsvik
- Gothenburg
- Kalmar
- Sundsvall
- Gävle
- Stockholm
- Malmö
- Södertälje
- Piteå
- Skelleftehamn
- Oxelösund
- Uddevalla
- Helsingborg

Denmark:

- Fredericia
- Copenhagen

Germany:

- Rostock
- Lübeck
- Wismar

Poland:

- Gdynia
- Gdansk
- Szczecin,Swinoujscie

Lithuania:

- Klaipeda
- Butinge

Latvia:

- Liepaja
- Riga
- Ventspils

Estonia:

- Tallinn
- Miiduranna
- Sillamäe
- Kunda

Russia:

- Vyborg
- Vysotsk
- Primorsk
- St Petersburg
- Ust-Luga
- Kaliningrad

Appendix G: Properties of some chemicals

(by Tuula Kuusela, Finnish Environment Institute)

Ammonia NH_3

Ammonia is a colourless gas with a strong pungent odour. Ammonia is liquefied by compression for transportation and storage.

UN number 1005
Category D
CAS number [7664-41-7]
Specific gravity 0.817 at 79 °C
Class 2.3
Density 620 kg/m^3
Molecular weight 17.04 g/mol
Solubility in water 53 1,000 mg/1
Melting point –78.27 °C
Boiling point –33.49 °C.
Autoignition temperature 630 °C
Gas density 0.68 (air: 1)

Ammonia is a base. Its pH in 1N water solution is 11.6. Ammonia is an important raw material when synthesizing different kinds of chemicals like nitric acid, hydrochloric acid, ammonium chloride, ethanolamine and amides and further producing fertilizers, plastics, explosives and pharmaceuticals, among others. Ammonia solutions (5–10%) are used as household cleaners. A huge amount of pure ammonia is needed for cooling different kinds of refrigerators.

Ammonia is transported by LPG carriers (Liquefied Pressurized Gas C.) as are other gaseous chemicals like petroleum gases, propane, butane and mixtures of these two, and petrochemical gases like ethylene, propylene, butadiene and vinyl chloride monomer. During a spill situation at sea, spilled ammonia is partly in its original form (NH_3) and partly in ionic form ($NH_4^+ OH^-$), which is less toxic than ammonia itself. Despite this, ammonia is very toxic to the marine environment. The effects are significant in a spill situation at sea, when most of the ammonia is still in its original gaseous form (NH_3).

The lethal amount of ammonia to man is about 1,700 ppm, but severe toxic effects are caused in 1 minute if the amount of ammonia is 500 ppm. Symptoms of illness appear when the amount of ammonia in water is 200 ppm. Ammonia also has remarkable effects on the marine environment. The LC 50 value on fish mg/l (Salmo gairdneri) is 0.056 mg/l during 72 h; half of the fish population tested died. Conifers were exposed to 0.61–0.36 ppm for 50 days under winter conditions, causing heavy injury.

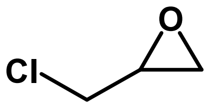
Literature

Svenska Brandskyddsföreningen, Farlig Gods-pärmar, updated cards

NPI: Ammonia (total) fact sheet, http://www.npi.gov.au/database/substanceinfo/profiles/8.html

Nikunen, E., Leinonen, R., Kemiläinen, B. & Kultamaa, A., 2000. Environmental Properties of Chemicals, vol. 1, p. 95. Helsinki: Finnish Environment Institute. ISBN 951-37-2967-2 (publisher), ISBN 952-11-0670-0 (co-publishers), ISSN 1238-8602.

Epichlorohydrin (1-Chloro-2,3 epoxypropane)



Epichlorohydrin is a colourless organic liquid with a garlic-like odour. It is used in the manufacturing processes of epoxy resins, surface active agents, pharmaceuticals, insecticides, fumigants and agricultural chemicals.

UN number 2023
Category A
CAS number [106-89-8]
Specific gravity 1,183
Class 6.1
Density 1,180 kg/m^3
Molecular weight 92.52 g/mol
Solubility in water 6.6%

Melting point –48 °C
Boiling point +117 °C
Autoignition temperature 385 °C
Gas density 3.2 kg/m^3

Epichlorohydrin is highly reactive and flammable. Its flashpoint is +32 °C. It will polymerize if heated or in conditions of high concentration of strong acid or base, and when it is in contact with halides salts, alcohols, phenols, amines (aniline) and metals like zinc or aluminium. Fire gases may contain hydrogen chloride, phosgene and carbon monoxide. There are acute health hazards and fire hazards. Epichlorohydrin is an irritant to the skin and carcinogenic. U.S EPA has found that epichlorohydrin causes short-term health effects to people exposed to the substance. These include skin irritation and detrimental effects on liver, kidneys and the central nervous system. Long-term effects include stomach, eye and skin irritation, chromosome aberrations, adverse changes in blood, and cancer.

Epichlorohydrin is used to make numerous substances, mainly synthetic glycerines and unmodified epoxy resins as a building block in making elastomers and water treatment resins, glycidyl derivates, plastisizers, surfactants, dyestuffs, emulsifiers, pharmaceuticals, adhesives and lubricants and insect fumigants. It is a solvent for cellulose, resins, rosins, paints and pesticides. Epichlorohydrin is a stabilizer in chlorine-containing substances.

During a spill situation at sea, the best response method is water spray, but do not direct a stream of water-jet to the surface of the spill. Gas and vapours are dispersed with a water spray on the surface of the burning liquid. Epichlorohydrin is a marine pollutant. Adsorption is safe only with vermiculite or sand.

Literature

Svenska Brandskyddsforeningen, Farlig Gods-pärmarna, updated cards

http://www.chemicalland21.com/arokorhi/petrochemical/EPICHL...

Parfomak, P. W. & Frittelli, J., 2005. Resources, Science and Industry, Division. CRS Report for Congress, Marine Security of Hazardous Chemical Cargo, August 26, 2005.

http ://www.epa.gov/safewater/contaminants/dw_contamfs/epichlor.html.

Solvay Chemicals, MSDS No. EPI-0405, Revised 04-24-05,
www.solvaychemicals.us 1.800.765.8292.

Soybean oil and others

$$\begin{array}{l} CH_2OCOR_1 \\ | \\ CHOCOR_2 \\ | \\ CH_2OCOR_3 \end{array}$$

Vegetable oils are fatty esters of glycerol (triglycerides) containing a hydrocarbon chain of fatty acids. Chains are typically different in length and in the number of double bonds present. The fatty acids in vegetable oils are lauric 12:0, palmitic 16:0, stearic 18:0 oleic 18:1, linoleic 18:2, linolenic 18:3, erucic 22:1 and recinoleic 18:1.

Biodiesel is made from used or new vegetable oil. EU Directive 2003/7307/EU has set a target of 2% bio-fuel use by end 2005 and 5.75% by end 2010. There have been discussions at EU level as to whether re-use oil should be banned. From autumn 2004 it is no longer permitted to re-use waste animal oils. Used vegetable oils can be burned in power stations, producing fairly “clean” energy, or they may be used as a lubricant. Soybean oil is less expensive than most other types of vegetable oils but more expensive than regular diesel fuel. Animal fat is also more expensive, but used oils from restaurants have been tried for biodiesel. The most promising forms of vegetable oils are methyl, ethyl and butyl esters.

The accident of *Allegra* in October 1997 in the English Channel caused a spillage of 900 tons of palm nut oil. The drift of this solid vegetable oil was followed by aerial observations. Samples of oil were collected in order to analyze its chemical evolution. This study, associated with several bibliographic cases of pollution by non-petroleum oils, shows that drifting oils can mix with floating material to sink or form a crust. They can also be oxidized or disperse and/or be degraded by bacteria. They may also polymerize. The coating properties of vegetable oils make them act like crude oils and affect sea life, tourism and yachting. As a result, it is necessary to quickly collect the oil after a spillage, using ordinary equipment (booms and pumps).

In the revised IBC Code the previous generic entries for vegetable oils have been deleted and replaced by a number of entries for individually identified vegetable oils. All these new entries are given with their pollution category as Y and do basically require a chemical carrier ship type 2, and contain a limit on free fatty acid content. *Guidelines for the transport of vegetable oils in deep tanks or in independent tanks specially designed for the carriage of such vegetable oils on board dry cargo ship* was also adopted by IMO in October 2004. It allows general dry cargo ships that are currently certified to carry vegetable oil in bulk to continue to carry these vegetable oils on specific trades (e.g. export from small Pacific islands where chemical tankers do not normally operate).

Literature

Peterson, C. L. & Auld, D. L., 1991. Technical overview of vegetable oil as a transportation fuel. Moscow, Idaho: Department of agricultural engineering, University of Idaho.

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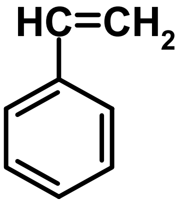
Bugas, G. & Saliot, A., 2002. Sea transport of animal and vegetable oils and its environmental consequences. Mar Pollut Bull, Vol. 44, No. 12, pp. 1388–1396. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retri eve &db=...

PMID: 12523544 [PubMed-index for MEDILINE 4].

http://www.imo.org/Environment/mainframe.asp?topic_1d=236.

Styrene monomer



UN number 2055
Category A
CAS number [100-42-5]
Specific Gravity 3.6
Class 3
Density 906 kg/m ^{3}
Molecular weight 104.16 g/mol
Solubility in water 300 mg/1

Melting point –31 °C
Boiling point +146 °C
Flash point +31 °C
Autoignition temperature +490 °C
Gas density 3.6 kg/m ^{3}

Styrene monomer is most commonly used in the production of valuable styrene polymers, which are either solid (SPS) or expandable (EPS). Some SPS grades are useful in the fabrication of a block for thermal insulation and boxes for vegetables and fruits. High impact polystyrene (HIPS) is polystyrene blended with rubber. It is possible to make packaging materials and co-polymers with rubber. Styrene monomer is stored in ordinary carbon steel tanks with tertiary butylcatechol (TBC at 10–15 ppm) to inhibit exothermic polymerization. One must avoid contact with styrene (containing low levels of TBC). Styrene is flammable, and it reacts with oxygen and creates hazardous peroxides.

Styrene can form explosive peroxides, and the substance may polymerize due to warming, under the influence of light and on contact with many compounds such as oxygen and oxidizing agents, peroxides and with strong acids. Styrene composes on burning and produces toxic fumes and styrene oxide. If the bulk styrene temperature rises to levels at which polymerization is self-sustaining and very rapid, this results in the release of large quantities of heat together with volumetric expansion. Styrene has several synonymous names, like vinylbenzene, cinnamol and phenylethylene. Styrene is a colourless flammable liquid that causes irritation to the eyes, skin and respiratory tract. The vapour causes coughing and shortness of breath and has a narcotic effect.

In the case of an accidental spill, use appropriate PPE and recover spill when possible by using vermiculite or sand or other material that does not burn, and place the polluted stuff into the waste container. When released into the water, the material is expected to readily biodegrade and to quickly evaporate, and in air this material is expected to have a half-life of less than 1 day. Despite styrene's TBC is soluble in water, and the environmental toxicity for fish is 1–10 mg/1. On the basis of this knowledge it is necessary to keep floating spills as far as possible from the nearest coast by using booms.

Literature

Svenska Brandskyddsföreningen, Farlig Gods-pärmama, updated cards.

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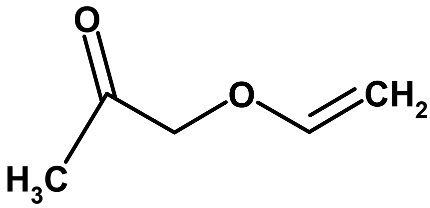
Vinyl acetate



UN number 1301
Category B
CAS number [108-05-4]
Specific Gravity 3.0
Class 3
Density 932 kg/m^3
Molecular weight 86.09

Solubility in water 20,000 mg/1
Melting point –93.2 °C
Boiling point +73 °C
Autoignition temperature +425 °C
Gas density 3.0 kg/m^3
Flash point –8 °C

Vinyl acetate is an economically important chemical with a wide variety of industrial and commercial applications. Vinyl acetate monomer is a chemical building block used to manufacture a wide variety of polymers: polyvinyl acetate, polyvinyl alcohol, polyvinyl acetals, ethylene vinyl acetate copolymers and ethylene vinyl alcohol. These polymers are commonly used in the production of plastics, films, lacquers, laminating adhesives, elastomers, inks, water based emulsion paints, finishing and impregnation materials, paper coatings, floor tiling, safety glass, building constructions, acrylic fibres and glue.

Vinyl acetate is an industrial chemical that is produced in large amounts in the United States. It is a colourless liquid and very flammable. It may be ignited by heat, sparks or flames. Exposure to vinyl acetate occurs mainly in the workplace. The major effect experienced from breathing high levels of vinyl acetate is skin and eye irritation. The International Agency for Research on Cancer has determined that vinyl acetate is not carcinogenic to humans. Vinyl acetate is stable, highly flammable and incompatible with acids, bases, oxidizing agents, peroxides, sulfonyl acids, ethylene imine, hydrochloric acid, oleum, nitric acid, sulphuric acid, 2-arninoethanol, light. Stabilization is achieved by using an addition of hydroquinone.

If vinyl acetate is released into the environment in a spill situation, significant polymerization may occur. Vapour-phase vinyl acetate degrades rapidly in the atmosphere by reaction with photochemically produced hydroxyl radicals. Vinyl acetate has an estimated half-life of 14.6 hours in average atmosphere. The aqueous hydrolysis half-life of vinyl acetate at 25 °C and pH 7 has been reported to be 7.3 days.

Literature

Svenska Brandskyddsföreningen, Farlig Gods-pärmarna, updated cards.

Vinyl Acetate Council-What is Vinyl Acetate.
http://www.vinylacetate,org/what.shtml.

ATSDR-ToxFAQs, http://www.atsdr.cdc.gov/tfacts59.html.

Safety (MSDS) data for vinyl acetate,
http://ptcl.chem..ox.ac.uk/MSDS/Vl/vinylacetate.html.

Nikunen, E., Leinonen, R., Kemiläinen, B. & Kultamaa, A., 2000. Environmental Properties of Chemicals, vol. 1, p. 1137. Helsinki: Finnish Environment Institute. ISBN 951-37-2967-2 (publisher), ISBN 952-11-0670-0 (co-publishers), ISSN 1238-8602.

Ethanol CH_3CH_2OH

UN number 1170
Category A
CAS number [64-17-5]
Class 3
Density 790 kg/m^3
Flammability zone 3.3–19 vol%
Miscible with water

Solubility in water: soluble
Melting point –117.3 ºC
Boiling point +78.5 ºC
Flash point +13 ºC
Molecular weight 46.07
Density 0.789

Ethanol is transported in liquid bulk in the form of pure alcohol (96%) and in its water solutions onboard chemical tankers in normal temperature. Tanks are equipped with closed circulation. Ethanol, ethyl alcohol has been made since ancient times by fermentation of sugars. Nowadays more than half of industrial ethanol is still made by this process. Yeasts zymase-enzyme changes the simple sugars to ethanol and carbon dioxide. The concentration of ethanol may rise up to 14%. Ethanol amount higher than 14% destroys zymase.

Ethanol is normally concentrated by distillation, when maximum amount of ethanol is 96%. Pure ethanol cannot be obtained by distillation. Most industrial ethanol is denatured to prevent its use as a beverage. Nowadays ethanol is made from acetaldehyde, acetylene or from ethylene, which is made from petroleum.

Ethanol is used for production of several important chemicals, like pharmaceuticals. Ethanol is used as a solvent of paints and in electroplating and as a cleaning substance. Ethanol is an alcohol-based alternative fuel produced by fermenting and distilling starch crops that have been converted into simple sugars. Ethanol is most commonly used to increase octane-value and improve the emission quality of gasoline. Ethanol can be blended with gasoline to create E85, a blend of 85% ethanol and 15% gasoline. It is possible to blend even 95% ethanol. Many vehicles on the road today can run on blends of ethanol and gasoline. There is a good market outlook for ethanol, because it can be produced from corn, barley, wheat, cellulose and also municipal solid waste. The vegetable based blends are common in USA, but in Europe biodiesel and other alternatives are already in use.

Literature

IMDG-code 2004 edition.

Ethanol, Industrial uses, http://www.scorecard.org/chemical-profiles/uses.tcl?edf _substance.

SBF, Svenska brandskyddsföreningen, Farligt gods pages, page 7.

Chemical of the Week – Ethanol.
http://scifun.chem.wise.edu/chemweek/ETHANOL/ ethanol.html.

Alternative Fuels Data Center:
Ethanol,http:/www.eere.energy.gov/afdc/altfuel/eth_market.html.

Methanol CH_3OH

UN number 1230
Category B
Subsidiary risk 6.1
CAS number [67-56-1]
Class 3
Flammability zone 6.0–36.5 vol%

Solubility in water is good
Melting point –93.9 ºC
Boiling point +64.96 ºC
Flash point +12 ºC
Molecular weight 32.04
Density 0.7914

Methanol is transported in liquid bulk on chemical tankers in normal temperature. Tank onboard bulk cargo vessel is equipped with a closed circulation of gaseous methanol to liquid. Methanol is transported in the form of pure alcohol or its water solutions.

Methanol is colourless liquid and dangerous to human health when breathing or drinking it. It evaporates easily and it causes blindness when drinking it. Methanol penetrates the skin to the bloodstream system.

Methanol is expected to exist almost entirely in the vapour phase in the ambient atmosphere, based on its vapour pressure. It is degraded by reaction with photochemical produced hydroxyl radicals with estimated half-life of 17,8 days in a typical ambient atmosphere. Atmospheric methanol can also react with nitrogen dioxide in polluted air to yield methyl nitrite. Methanol in aqueous solution exhibited no degradation when exposed to sunlight using an EPA test protocol. Methanol is very dangerous chemical to marine environment causing damage to animals and plants.

Methanol is used as a solvent and in manufacturing processes of formaldehyde, methyl chloride, sodium borohydrin, methyl tert-butylether (MTBE), formic acid and also in the production of acid methyl esters. Methanol is used on limited quantities in fuels and anti-freezing agents. Methanol is a solvent for paints, lacquers, greases, corrode aluminium and lead. In the 1990s, large amount of methanol was used to produce gasoline additives. Later it was found that MTBE had leaked out of fuel storage tanks into the groundwater in the USA. MTBE was found to be a carcinogen in animal tests. The ester derivatives of methanol do not share this toxicity. Methanol burns in air forming carbon dioxide and water: $2CH_3OH + 3O_2 \rightarrow 2\ CO_2 + 4\ H_2O$.

Literature

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SBF, Svenska brandskyddsföreningen, Farligt gods pages, p. 18.

Nikunen, E., Leinonen, R., Kemiläinen, B. & Kultamaa, A., 2000. Environmental properties of chemical, vol. 1. Helsinki: Finnish Environment Institute. ISBN 951-37-2967-2 (publisher), ISBN 952-11-0670-0 (co-publishers), ISSN 1238-8602.

Appendix H: Potential oil outflow based on IMO's Marpol Annex I Regulations 13F and 13G, in the case of single hull tankers (Daidola et al., 1997)

Baseline tanker model	13F Mean oil outflow — bottom			13F Mean oil outflow side (m*3) (Bbls)	13F Total mean oil outflow (m*3) (Bbls)	Regulation 13G outflow			% Outflow of total cargo carried		Difference between 13F & 13G	13F Total extreme oil outflow (m*3) (Bls)
	Tidal drop (0 m) (m*3) (Bbls)	Tidal drop (2 m) (m*3) (Bbls)	Tidal drop (6 m) (m*3) (Bbls)			Side (m*3)	Bottom (m*3)	Total (m*3)	13F	13G		
40600 DWT Pre-MARPOL	1408	322	6801	2351	2652	2588	999	1635	5.35%	3.30%	2.05%	5920
	8854	020255	42779	14787	16683	16279	6295	10283				37233
40600 DWT MARPOL '78	1944	3481	6523	1003	2303	787	2004	1517	5.49%	3.62%	1.87%	7244
	12227	21894	41029	6306	14487	4949	12607	9544				45565
71000 DWTpre-MARPOL	1345	4458	10639	4872	4247	4199	2031	2898	5.04%	3.44%	1.60%	11478
	8461	28043	66920	30641	26715	26412	12775	18230				72192
71000 DWTMARPOL '73	3268	6208	12019	3457	4750	3761	3492	3599	5.50%	4.17%	1.33%	12902
	20553	39046	75596	21743	29879	23654	21964	22640				81151
71000 DWTMARPOL'78	4147	7313	13603	2337	4940	1796	4605	3482	5.92%	4.17%	1.75%	15402
	26081	45997	85558	14701	31072	11296	29966	21898				96878
152000 DWT MARPOL '73	6646	10681	18689	6727	8612	6304	8206	7445	5.01%	4.33%	0.68%	24033
	41805	67182	117548	42314	54166	39649	51614	46828				151161
152000 DWT MARPOL'78	7625	11764	19985	6116	9005	5130	8769	7314	5.28%	4.29%	0.99%	26692
	47962	73994	125705	38467	56638	32268	55158	46002				167890
268000 DWTpre-MARPOL	565	6966	203501	18046	10664	18322	4532	10048	3.23%	3.04%	0.19%	27044
	3552	43810	27995	113503	67076	115245	28503	63200				170100
268000 DWTMARPOL'73	9583	14890	25436	14415	14059	14882	11043	12578	4.28%	3.83%	0.45%	38.205
	60276	93638	159987	90669	88430	93602	69459	79116				240300
268000 DWTMARPOL '78	12550	18600	30626	11366	14976	9736	14083	12344	4.66%	3.84%	0.82%	44625
	78940	116990	192633	71489	94196	61238	88579	77643				280681
14910 GRT ocean barge	45	1294	4396	1977	1454	2088	234	976	3.66%	2.46%	1.20%	3686
	284	8141	27653	12437	9144	13136	1.474	6139				23184
6530 GRT coastal barge	18	854	2968	1593	1076	1835	40	758	6.54%	4.61%	1.93%	2473
	115	5371	18667	10018	6766	11542	254	4769				15555

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Author(s)
Hänninen, Saara & Rytkönen, Jorma

Title
Transportation of liquid bulk chemicals by tankers in the Baltic Sea

Abstract
While gathering information about oil transportation for VTT Publication 547 *Oil transportation and terminal development in the Gulf of Finland* (2004) the question about other harmful substances transported in liquid bulk was raised. The Finnish Ministry of the Environment, Finnish Environment Institute (SYKE) and Finnish Maritime Administration (FMA) have made it possible for us to continue the work on tanker transportations by financing this study. The area has been widened to cover the entire Baltic Sea. This publication introduces the statistics concerning the chemicals handled in liquid bulk in the Baltic Sea ports in 2004. Some of the ports have expressed their concern about giving what they consider to be sensitive information; alas, the data in this report is not to be considered full and complete, but it does give an indication of where chemical tankers are sailing.

Marine chemical transportation is constantly growing in regard of the number of chemicals and the total volume of goods transported. Today, the number of different substances and compounds is quoted in thousands. A great many of these chemicals are dangerous to the environment, and even though the risk of a chemical accident is considered small due to very high standards regarding safety, it does exist. Based on the statistics, the most important chemicals transported in the Baltic were chosen for further examination.

Keywords
chemicals, chemical transport, maritime transport, Baltic Sea, environmental impacts, safety, pollution, tankers, ports, harbours

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Contact
VTT Technical Research Centre of Finland
P.O. Box 1000, FI-02044 VTT, Finland
Phone internat. +358 20 722 111
Fax +358 20 722 7076

Sold by
VTT
PL 1000, 02044 VTT
Puh. +358 20 722 4404
Faksi +358 20 722 4374

This publication introduces the statistics concerning the chemicals handled in liquid bulk in the Baltic Sea ports in 2004. The data is based on the public registers, data files and announcements of port authorities and operators. A special questionnaire on transported chemicals, and specifically on bulk form chemicals, was made for ports.

Some of the most dangerous or most common chemicals were selected and briefly analysed on the basis of their environmental impact if released into the water. The risk of chemical outflow has also been discussed within the collision and grounding modes. A special chapter related to the Northern Baltic waters has been written on the risk of winter navigation for chemical transportation. Discussion has also been carried out on the fate of chemicals spilled on water and on the physical fundamentals when trying to control them; finally, some scenarios are presented on potentially high-risk areas.

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Saara Hänninen & Jorma Rytkönen

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