TURUN YLIOPISTO
MERENKULKUALAN KOULUTUS- JA TUTKIMUSKESKUS

CENTRE FOR MARITIME STUDIES
UNIVERSITY OF TURKU

2010

MARITIME TRANSPORT OF CHEMICALS IN THE BALTIC SEA

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European Union
European Regional Development Fund

Leverage from the EU
2007–2013

KYMENLAAKSON LIITTO
REGIONAL COUNCIL OF KYMENLAAKSO

MERI KOTKA

ABSTRACT

Hazardous substances are solids, liquids, or gases that can harm people, other living organisms, property, or the environment. This study handles the maritime transport of hazardous substances other than oil and oil products. These substances are transported in high amounts also in the Baltic Sea. Different substances have different properties and thus they may behave in various ways when released into the water. The Baltic Sea is highly sensitive sea area, partly because of its limiter water exchange. Thus chemical accidents could have serious impacts on its environment. The sea is also particularly difficult to navigate, which further increases the risks of maritime chemical transport. Fortunately, industries and governments have already adopted and implemented several strict regulations regarding both maritime safety issues and pollution prevention. In addition, new regulations and technical innovations are introduced to the industry all the time. Comprehensive statistics about the chemical transportations is difficult to get as compatible data from all the Baltic Sea countries is not available. However, there are some case studies presented here. Also a few previous studies about the maritime chemical transport are reviewed in this study. Not many of these studies are comprehensive and many are already outdated. The final part of this study is concentrated on the chemical accidents in the marine environment.

TIIVISTELMÄ

Vaaralliset aineet ovat joko kiinteitä, nestemäisiä tai kaasumaisia aineita, jotka voivat aiheuttaa vahinkoa ihmisille, omaisuudelle tai ympäristölle. Tässä tutkimuksessa käsitellään muiden vaarallisten aineiden kuin öljyn ja öljytuotteiden merikuljetuksia. Näitä aineita kuljetetaan Itämerellä runsaasti. Eri aineilla on omat ominaisuutensa ja siten ne voivat veteen joutuessaan käyttäytyä hyvinkin eri tavalla. Kemikaalionnettomuudet saattavat olla hyvinkin tuhoisia ympäristölle. Erityisesti tämä on huolestuttavaa Itämeren kannalta, koska Itämeri on maailmanlaajuisestikin ainutlaatuinen ja hyvin herkkä merialue. Itämerellä navigoiminen on haastavampaa kuin monella muulla merialueella, mikä osaltaan lisää kemikaalionnettomuuden mahdollisuutta. Lukuisia lakeja, sopimuksia ja muita toimenpiteitä on kuitenkin jo tehty merenkulun turvallisuuden parantamiseksi ja meren saastuttamisen ehkäisemiseksi. Lisäksi uusia määräyksiä ja teknisiä innovaatioita esitellään alalle jatkuvasti. Kattavia tilastojen Itämeren kemikaalikuljetuksista on vaikea saada, sillä eri maiden keräämät tilastot eivät ole vertailukelpoisia. Tässä tutkimuksessa käydään kuitenkin läpi muutamia esimerkkitilastoja. Samoin tutkimuksessa tutustutaan aikaisempiin vaarallisten aineiden merikuljetuksia käsitteleviin tutkimuksiin. Kattavia tutkimuksia aiheensa on hyvin vähän ja niidenkin tiedot alkavat olla jo vanhentuneita. Tutkimuksen loppuosassa keskitytään merellä tapahtuviin kemikaalionnettomuuksiin.

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1 INTRODUCTION

Chemicals and hazardous substances are widely used in many purposes, for example as raw materials in various industry sectors (Häkkinen 2009: 1). Thus the number of different chemicals transported is enormous. Different substances have different physical and chemical properties and thus they behave in very different ways when released into the water. Consequently, the modelling of environmental impacts is difficult and hence also the equipping and preparing for the possible accidents is challenging.

The great demand of chemicals leads to great transportation volumes, and these volumes are increasing globally (ITOPF s.a.). The trend exists also in the Baltic Sea region as both the number of chemicals and the volume of goods transported have increased in the area during last decades. The figures are expected to grow also in the future (Hänninen & Rytkönen 2006: 105–106). Fortunately, the number of large scale chemicals releases has declined at the same time (Hänninen & Rytkönen 2006: 4). This is probably due to the phase out of single hull tankers, stricter legislation, and new technical equipments. However, none of these actions can prevent accidents entirely, but it is always possible to learn from ones mistakes. Therefore, old chemical accidents of the Baltic Sea are shortly summarised at the end of this report.

This study explores the current state of the chemical transportations in the Baltic Sea region. The main purpose is to evaluate the quality and the quantity of the information available about the subject. Previous studies are reviewed and the need for new ones is estimated. Some transportation statistics, both national and international, are also introduced and small case studies made. The usability and comparability of these statistics is also estimated. This study can be used as general background information when new research projects are planned.

This report has been written as a part of the research project “SAFGOF – Evaluation of traffic increase in the Gulf of Finland 2007-2015 and the effect of the increase on the environment and traffic chain activities” of Kotka Maritime Research Centre. The research project is financed by the European Union – European Regional Development Fund – Regional Council of Kymenlaakso, the City of Kotka, Kotka-Hamina regional development company Cursor Ltd., Kotka Maritime Research Association Merikotka and the following members of the Kotka Maritime Research Centre Corporate Group: Port of Hamina, Port of Kotka and Arctia Shipping Oy (formerly Finstaship). The report has been written by Hanna Luhtala, a trainee in the Centre for Maritime Studies of the University of Turku, under supervision of M. Soc. Sc. Jenni Kuronen, Ph.D. Jani Häkkinen, and Professor Ulla Tapaninen.

2 GENERAL BACKGROUNDS

2.1 Maritime transportation of chemicals

2.1.1 Definitions

Hazardous substances are solids, liquids, or gases that can harm people, other living organisms, property, or the environment. This includes substances that are for example flammable, explosive, radioactive, corrosive, oxidizing, toxic, pathogenic, etc. Hazardous substances are used as raw materials in various industry sectors, related for example to forestry, pharmacy, electronics, and manufacturing of plastics, paints, rubbers, etc. Also many consumer goods, like aerosols and paints, are transported as hazardous substances even though they are directed straight to retail sale. Absolutely the biggest portion of transported hazardous substances consists of oil related substances (Häkkinen 2009: 1). In other words, not all the hazardous substances are chemicals as such.

The transportation of chemicals differs from the transportation of oils and oil products. Chemical transportations require more advanced tankers and handling (INTERTANKO 2006: 2). Hazardous substances can be transported either in bulk or packaged form. Bulked substances can be further divided into solids, liquids, and gases (figure 2.1), and those can be transported either by chemical carriers or by gas carriers (Hänninen & Rytkönen 2006: 15). In the Baltic Sea most of the chemical transportations are done by chemical parcel tankers that consists typically 10 to 60 separate cargo tanks (Hänninen & Rytkönen 2006: 22). Several different chemicals can thus be carried in one ship at the same time.

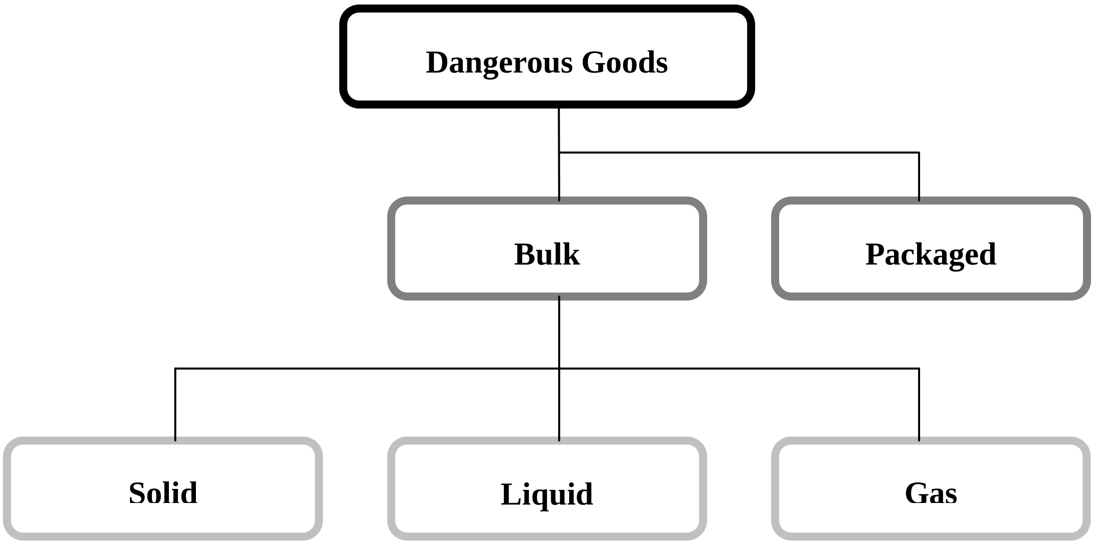

Figure 2.1. Dangerous goods can be transported in various forms. (Hänninen & Rytkönen 2006: 15)

There are two kinds of tanker structures, so called single hull tankers and double hull tankers. In single hull tankers, the cargo is separated from the seawater only by a bottom and a side plate. Whereas, in double hull tankers there is a second internal plate at a sufficient distance from the external plate to strengthen the bottom and sides of the ship (Anon. 2007b). In a case of a collision or grounding the external layer is easily damaged. In these situations the risk of a serious pollution is much higher with single hull tankers than with double hull tankers. Because of their serious risk to environment, the phase-out of single hull tankers has been started by IMO in 1992. The phase-out timetable has been tightened many times since then. Most of the single hull tankers should be modified to double hull tankers or removed from a use entirely by the end of this year, 2010 (IMO s.a./c).

Some cargoes require special conditions. Others need heating or cooling; others react so violently with water that they need to be kept in ultra-dry conditions; others must be kept in motion; and so on. Many chemicals are so flammable, corrosive, or toxic that safety issues are extremely important. Also some chemicals react vigorously to other substances or to exposure to the atmosphere (Hänninen & Rytkönen 2006: 22–23). The list of special requirements is extensive.

The most commonly transported bulk chemicals and chemical products in the world are:

- Heavy chemical products made in large quantities
- Molasses and alcohols
- Vegetable oils (soya, palm nut, sunflower, etc) and animal oils (lard, fish oils)
- Petrochemical products (benzene, xylene, phenol, styrene, etc)
- Coal tar products (benzene, phenol, naphthalene, etc).

Furthermore, the most common heavy chemical products are sulphuric acid, phosphoric acid, nitric acid, chlorhydric acid, caustic soda and ammonia. (Bonn Agreement 2000)

2.1.2 Physical properties and behaviour of chemicals

It is crucially important to know the physical properties of the chemicals transported in ships. Different chemicals behave in different ways when released into the sea. They can evaporate, float, dissolve or sink. Behaviour depends on physical properties of the chemical and also on the environmental conditions of the sea. Substances can be categorised into physical property groups by certain limits of vapour pressure, density, solubility, and viscosity. Different limits are used for substances in different physical state, in other words for gaseous, liquid, and solid chemicals. Categories help officials in a case of spillage or accident since chemicals in the same property group behave in similar ways. (Hänninen & Rytkönen 2006: 17–20)

In reality, substances released into water behave often in more complex manner than simply evaporate, float, dissolve, or sink. A chemical may behave in several ways simultaneously, for example evaporate into the air and dissolve into the water (Hänninen & Rytkönen 2006: 17–18). There are 12 property groups named in European behaviour classification system of Bonn Agreement (2006) (table 2.1). In addition, packaged chemicals can be divided into 3 more groups: packages that float (PF), immerse (PI), or sink (PS) (Bockholts 1988: figure 5).

Table 2.1. Categorisation of hazardous substances by their properties (Modified from HELCOM 2003: annex4, figure 4)

Behaviour category		**Examples**
Gas	G	propane, butane, vinyl chloride
Gas/dissolver	GD	ammonia
Evaporator	E	benzene, hexane
Evaporator/dissolver	ED	methyl-t-butyl ether, vinyl acetate
Floater	F	phthalates, vegetable oils, animal oils
Floater/evaporator	FE	heptane, toluene, xylene
Floater/dissolver	FD	butanol, butyl acrylate
Floater/evaporator/dissolver	FED	butyl acetate, isobutanol, ethyl acrylate
Dissolver	D	some acids ands bases, some alcohols, glycols
Dissolver/evaporator	DE	acetone
Sinker	S	coal tar, butyl benzyl phthalate
Sinker/dissolver	SD	dichloroethane

This simple classification system takes only one chemical into account at a time. This is problematic, because large chemical tankers carry several different chemical at the same time, and in case of an accident these chemicals may get mixed. A new compound may have totally different properties and behaviour than the original, separate chemicals had (Hänninen & Rytkönen 2006: 21). In any case, chemicals involved in the accident should be known before starting the rescue actions. For example, fire fighting methods should be chosen very carefully, because some chemicals react vigorously with water or emit toxic gases when wet (HELCOM 2003: annex 3). Recovery actions designed to oil spills are not always usable either, because the characteristics of chemicals, even the floating ones, may differ from the characteristics of oils (Hänninen & Rytkönen 2006: 86). Use of trade names in transportations is noted to be inappropriate, because it might complicate the identification of the cargo and chemical in question (HELCOM 2003: annex 3). Identification problems complicate the planning of rescue actions significantly.

Information about chemicals, their physical properties, and environmental impacts is available in numerous web pages of different organisations. For example, Cedre (s.a.) (Centre of Documentation, Research and Experimentation on Accidental Water Pollution) shares a few chemical response guides designed to allow rapid access to the necessary initial information needed in the event of a chemical release. Original versions of international chemical safety cards (ICSC) are in the web pages of ILO (The International Labour Organization). Original versions are in English, but cards have been translated to at least 15 other languages as well. For example, Finnish versions are to be found from the web pages of Finnish Institute of Occupational Health.

2.1.3 Classification systems of transported chemicals

The world is full of different classification systems concerning the transport, trade, stock, and handling of goods. Many of these systems include also classification of chemicals or hazardous substances. The IMDG code and MARPOL categories are the most important classification systems of maritime transportation of hazardous substances. These two systems regulate the maritime transport of hazardous substances.

However, chemicals are classified also in many of the standard trade classifications, like in SITC, NACE, CPA, NST, and CN (table 2.2).

Table 2.2. International classification systems that include chemicals or hazardous substances.

Name	**Used in**	**Maintained by**
MARPOL	Maritime transport: hazardous bulk	UN
IMDG	Maritime transport: packaged dangerous goods	UN
SITC	Foreign trade statistics	UN
CPA/NACE	Indicates the structure of import and export	EU
NST	Trade statistics	EU
CN	Export declarations and statistical declarations	EU

Beside numerous international classification systems, each country may have also national classifications. Usually these national systems are derived from some international systems, or are closely related to them. For example, national activity classifications of nine countries bordering the Baltic Sea are all related to the NACE system. The product classification systems of these countries are more various (UNSD 2003). Since the classification procedures are this diverse, classification can be changed to others with the help of correlation tables and conversion keys. Some good examples of correlation tables are found in the web pages of Finnish Customs (2009a, 2009b, 2009c).

IMDG code

Harmful substances in packed form are classified according to IMDG (The International Maritime Dangerous Goods) code into 9 main classes some of which are further divided into subclasses (IMO s.a./b). The classification is the same also in road (ADR) and rail (RID) transportations as the systems have been harmonised by GHS (Globally Harmonised System of Classification and Labelling of Chemicals) of the United Nations (UN). The harmonisation includes the classification categories and the labelling of the packages. Naturally there are some differences in practical manners related to the transport modes themselves. The classes are:

- 1: Explosives
  - 1.1: substances and articles which have a mass explosion hazard
  - 1.2: substances and articles which have a projection hazard but not a mass explosion hazard
  - 1.3: substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
  - 1.4: substances and articles which present no significant hazard
  - 1.5: very insensitive substances which have a mass explosion hazard
  - 1.6: extremely insensitive articles which do not have a mass explosion hazard
- 2: Gases
  - 2.1: flammable gases
  - 2.2: non-flammable, non-toxic gases
  - 2.3: toxic gases
- 3: Flammable liquids
- 4: Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases
  - 4.1: flammable solids, self-reactive substances and desensitised explosives
  - 4.2: substances liable to spontaneous combustion
  - 4.3: substances which, in contact with water, emit flammable gases

- 5: Oxidizing substances and organic peroxides
    - 5.1: oxidizing substances
    - 5.2: organic peroxides
- 6: Toxic and infectious substances
    - 6.1: toxic substances
    - 6.2: infectious substances
- 7: Radioactive material
- 8: Corrosive substances
- 9: Miscellaneous dangerous substances and articles

The IMDG code is maintained by International Maritime Organization (IMO) that is a specialised agency of the United Nations. The code is renewed every second year with amendments. The valid addition is Amendment 34-08 that came into force the first of January in 2010. The Amendment 35-10 has already been published and it can be voluntarily used from the beginning of year 2011 and it becomes obligatory in 2012. The code consists of three parts. First, (Volume 1) contains general regulations, definitions, etc. Dangerous goods are listed in the second part (Volume 2). And the third part (Supplement) has annexes, for examples Medical First Aid Guide (IMO s.a./b).

MARPOL categories

MARPOL 73/78 is an international convection for prevention of pollution of marine environments by ships. The Annex II of the MARPOL contract (regulations for the control of pollution by noxious liquid substances in bulk) introduces a categorisation system for noxious and liquid substances (IMO s.a./a). According to IMO (s.a./a) the four classes used in maritime transportation are:

- **Category X**: Noxious Liquid Substances which, 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 the discharge into the marine environment.
- **Category Y**: Noxious Liquid Substances which, 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 on the quality and quantity of the discharge into the marine environment.
- **Category Z**: Noxious Liquid Substances which, 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** (OS): substances which 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 of 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 categorisation has been changed a few years ago. The revision of Annex II replaced the old 5 category system with the current 4 category system. The old categories were A, B, C, D, and Appendix III. The revision entered into force the first of January in 2007 (INTERTANKO 2006: 11). For detailed information, see revised MARPOL Annex II (for example, LVM 2008, *in Finnish*). A list of chemicals with their new and old categories is presented in *The Revisions to MARPOL Annex II – A Practical Guide* (INTERTANKO 2006: 17–29).

SITC

Standard International Trade Classification (SITC) is a classification system maintained also by the United Nations. A current version, revision 4, entered into force the first of January in 2007. The system consists of 5 levels (Finnish Customs 2009c). There are 10 main categories at the top level:

0: Food and live animals
1: Beverages and tobacco
2: Crude materials, inedible, except fuels
3: Mineral fuels, lubricants and related materials
4: Animal and vegetable oils, fats and waxes
5: Chemicals and related products, not elsewhere specified
6: Manufactured goods classified chiefly by material
7: Machinery and transport equipment
8: Miscellaneous manufactured articles
9: Commodities and transactions not classified elsewhere in the SITC.

The total amount of classes at the 5th level is almost 3,000. The main category number five, chemicals and related products, is further divided into nine 2nd level categories:

51: Organic chemicals
52: Inorganic chemicals
53: Dyeing, tanning and colouring materials
54: Medicinal and pharmaceutical products
55: Essential oils and resinoids and perfume materials; toilet, polishing and cleansing preparations
56: Fertilisers (other than natural fertilisers)
57: Plastics in primary forms
58: Plastics in non-primary forms
59: Chemical materials and products, not elsewhere specified.

All in all, there are 467 subclasses under the category of chemicals. (Finnish Customs 2009c)

CPA and NACE

Statistical Classification of Products by Activity in the European Economic Community (CPA) classifies both transportable goods and non transportable goods and services. The classification system consists of six structure levels. At the first level, there are 17 sections that are named with alphabetic code (from A to Q). *Chemicals and chemical products* (category number 20) is one of the 24 subcategories belonging to class of *manufactured products* (category C). This category is further divided into six third level categories:

- C Manufactured products
  - 20 Chemicals and chemical products
    - 20.1 Basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms
    - 20.2 Pesticides and other agrochemical products
    - 20.3 Paints, varnishes and similar coatings, printing ink and mastics
    - 20.4 Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
    - 20.5 Other chemical products
    - 20.6 Man-made fibres

The first four CPA structure levels are compatible with NACE rev. 2 that is a similar classification system of the European Union (Statistics Finland s.a.). Although, the hierarchy continues until the sixth structure level, only the first four of them are same in all European countries. Further subcategories are national, for example Finnish national system is called TOL2008 (Finnish Customs 2009b). The current version CPA2008 replaced CPA2002, and entered into force in 2009 (Finnish Customs 2009a).

NST 2007

NST 2007 is a classification system with 20 main divisions and 81 second level groups. Number 08 of the main division contains different kinds of chemical, rubber and plastics products and also nuclear fuel (UNECE 2008). The groups are:

- 08 Chemicals, chemical products, and man-made fibres; rubber and plastic products; nuclear fuel
  - 08.1 Basic mineral chemical products
  - 08.2 Basic organic chemical products
  - 08.3 Nitrogen compounds and fertilisers (except natural fertilisers)
  - 08.4 Basic plastics and synthetic rubber in primary forms
  - 08.5 Pharmaceuticals and parachemicals, including pesticides and other agri-chemical products
  - 08.6 Rubber or plastic products
  - 08.7 Nuclear fuel.

In 2007 European Community published a regulation based on which NST 2007 entered into force in all the EU member states in 2008 (Anon 2007a). NST 2007 is a revision of NST 2000. However, the NST/R classification that was still in use in many countries before NST 2007 was implemented already in 1967. It had only five second level groups for chemicals (Eurostat s.a.).

CN

The Combined Nomenclature, CN, is a foreign trade related classification system of the European Community. All goods imported to the countries of the Community must be classified according to CN. The classification system is also used in intra-Community trade statistics (Anon. 2010). There are 21 main sections (I–XXI) in the CN system. The section VI contains products of the chemical or allied industries. Changes to the nomenclature are made every year and they are published in the Official Journal of the European Union (Finnish Customs 2010a). The valid classification, Combined Nomenclature 2010, contains detailed information about the listed goods and is almost 900 pages long (Anon. 2009a).

2.1.4 Laws and regulations

Maritime transportation of hazardous chemicals is strictly regulated. Substances are classifies according IMDG code (packaged) or MARPOL categories (bulk). The structure and equipments of the vessels transporting the substances are regulated as well. There are codes for ships carrying gaseous chemicals (IGC code), liquid bulk chemicals (IBC code), and solid bulk chemicals (BC code) (Häkkinen 2009: 5). A shipboard oil pollution emergency plan, SOPEP, is obligatory for every oil tanker over 150 grt (gross register tons) and every ship over 400 grt. In addition, every ship over 150 grt carrying noxious liquid substances must also have a shipboard marine pollution emergency plan, SMPEP (FMA 2002).

According to Hänninen and Rytkönen (2006: 4) the safety practices of chemical transportations are among the best in shipping industry. Industries and governments have already adopted and implemented several strict regulations regarding both safety issues and pollution prevention (Hänninen & Rytkönen 2006: 90). However, the new regulations and technical innovations are introduced to the industry all the time. For instance, maritime safety standards of the European Union were tightened up considerably after the accidents of oil tankers Erika and Prestige. One example of new measures is the establishment of European Maritime Safety Agency (EMSA) (Danklefsen 2010). At the same time VTS systems and AIS are examples of technical solutions that improve the safety of maritime transportation (Hänninen & Rytkönen 2006: 16). For good compilations about the laws and regulations, look for example, *Maritime Transport and Risks of Packaged Dangerous Goods* (Mullai 2006) and *Carriage of Dangerous Goods and Law – The Case of Finland* (Railas 2006). Short summaries about the subject can also be found in Hänninen and Rytkönen (2006: 24–28) and Häkkinen (2009: 4–14), and also in the action plan of EMSA (2007: 13–29). Also means of improving the maritime chemical transportations are discussed in Hänninen and Rytkönen (2006: 90–104).

2.1.5 Hazardous substances in the ports

According to the directive of the European Parliament and of the Council, a ship carrying hazardous substances needs to announce its intention to enter the European port at least 24 hours in advance or as soon as the destination port becomes known (Anon. 2002). Information about the hazardous cargo and also other information, such as notification about the voyage of the ship and incidents happened to ship, are gathered to SafeSeaNet system maintained by EMSA (EMSA 2010b). For example Finland fulfils the requirements by national PortNet system (Posti et al. 2010: 53).

The ports in Finland can themselves decide to some extent what kind of hazardous substances they handle. As defined in the EU directive a notification from all the incoming hazardous cargo must be given at least 24 hours before the arrival of the ship. However, in a case of the most hazardous substances permission must be asked from the port already three days earlier. The ports can specify certain areas dedicated to temporal storages of hazardous cargo. These storage areas are designed so that the harmful effects of a spill or accident are minimised. Also the cargo units are organised in a way that incompatible substances are not put next to each other. Some cargo types can not be stored at the port areas at all. In these cases cargo must be transported directly from road or rail to the ship or other way around. The units carrying dangerous goods must be marked with proper warning symbols. (Port of Turku 2009)

2.2 Baltic Sea

2.2.1 The unique, sensitive nature of the Baltic Sea

The Baltic Sea is a small and almost landlocked sea located in northern Europe. It is surrounded by nine countries: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, and Sweden. Over 85 million people live in its catchment area, the surface area of which is ca. 1,650,000 km^2. The surface area of actual sea area is ca. 393,000 km^2 and total volume is 21,000 km^3 (Myrberg et al. 2006: table 2.1). The Baltic Sea is the second largest brackish water basin in the world (Myrberg et al. 2006: 10).

The Baltic Sea is a unique sea area in many ways. First, it is a brackish water basin with average depth of only 54 meters (Myrberg et al. 2006: table 2.1). In comparison, the average depth of the Mediterranean Sea is ca. 1,500 meters and the Atlantic Ocean ca. 4,000 m (Myrberg & Raateoja s.a.). The exchange of water between the Baltic Sea and the North Sea is very slow. Therefore salinity of the Baltic Sea water is very low, decreasing from around 30 from the Danish Straights to close to zero in the north and east (Myrberg et al. 2006: 18). Limited water exchange makes the sea also highly sensitive to the environmental impacts of human activities. For example, if harmful substances are introduced into water, they will remain there for a very long time (Hänninen & Rytkönen 2006: 16).

Saline water, which is heavier than fresh water, sinks to the bottom of the sea and fresh water remains at the surface. This natural phenomenon creates a stagnant stratification called halocline. Halocline prevents the mixing of the two water layers and thus exchange of substances, like pollutants, too. Furthermore, the strong salinity barrier creates situations of oxygen depletion near the sea bottom, which in turn leads to release of toxic gas, hydrogen sulphide. In some years no less than one quarter of the surface area of the seabed is virtually lifeless due to oxygen depletion. (Hänninen & Rytkönen 2006: 17)

Secondly, the Baltic Sea is located between temperate and subarctic climate zones. Because of cold winters, large parts of the sea are ice covered every year. In severe winters the whole sea might get an ice cover (Myrberg et al. 2006: 9). This has naturally a huge effect on both the environment and winter trafficking. Also, physical, chemical, and biological decomposition of harmful substances is slower and more ineffective during cold winters and long periods of ice cover (FEI 2010a).

Thirdly, the brackish sea of today is really young. The sea basin was formed thousands of millions of years ago, but the present sea stage is only 2,000 years old (Myrberg & Raateoja s.a.). The history of the water body consists of consecutive stages of fresh and salty water (Myrberg et al. 2006: 15–17). The effects of the previous ice age are still detectable as isostatic land uplift. Uplift is strongest in the northern parts of the Baltic Sea, whereas the zero line lies somewhere south of Estonia, and below that sea level seems to even rise (Myrberg et al. 2006: 44). There are quite few species adapted to the sea. First of all, only a moderate number of species from purely oceanic or fresh waters have been able to adapt to the brackish waters of the Baltic Sea. Secondly, time after the previous ice age has been too short to own species to be evolved (Myrberg et al. 2006: 9–10).

The fourth peculiarity of the Baltic Sea is the lack of significant tidal action. The tidal variation is so small in the sea, that it is practically negligible (Myrberg et al. 2006: 126). Normally tides affect considerably to the controllability of a chemical spill, but in the Baltic Sea tidal influence can be neglected (Hänninen & Rytkönen 2006: 87). However, there are other kinds of irregular or regular movements of water masses. Principally, water flows anticlockwise in the Baltic Sea. For example, in the Gulf of Finland, water flows eastwards in the Estonian coast and westward in the Finnish coast. The main reasons for this pattern are winds, the shape of the coastline, and Coriolis effect (Virtaustutkimuksen neuvottelukunta 1979: 69). Of course, there are also local currents of different magnitude, direction, and duration.

The environmental condition of the Baltic Sea is quite poor. Eutrophication is a major problem and for its part worsens the problem of anoxic bottom water. Hazardous substances are a serious problem too, since the entire Baltic Sea is at least somewhat disturbed by them. Key substances of concern are PCBs, heavy metals, DDT/DDE, TBT, dioxins, and brominated substances. (HELCOM 2010a: 14)

In 2005 the Baltic Sea, with the exception of Russian waters and the Russian economic zone, was designated a Particularly Sensitive Sea Area (PSSA) by IMO. The definition of PSSA is following:

> “A Particularly Sensitive Sea Area is an area that needs special protection through action by IMO because of its significance for recognised ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.”

The recognition of the especially sensitive nature of the Baltic Sea has allowed stricter requirements for maritime transport than in other areas. The Baltic Sea has also been defined as a special area in many of the annexes of MARPOL 73/78 convention. (FEI 2009)

2.2.2 Navigational problems of the Baltic Sea

According to HELCOM, shipping has increased significantly around the Baltic Sea during recent years. Around 2,000 sizeable ships are at the Baltic Sea at any time, and the number is predicted to increase even further (HELCOM 2010b: 8). Already twenty years ago about 35 ships with packaged dangerous goods (HELCOM 1993: 3), 23 loaded chemical tankers and 3–4 loaded gas carriers were in continuous operation in the Baltic Sea at any time (HELCOM 1990: 4). Equally important is that the size of ships has also grown. With up to 15 % of the world's cargo transportation, the Baltic Sea is one of the most heavily trafficked seas in the world (HELCOM 2009: 3). Unfortunately, the continuous rise in shipping is also resulting in increasing risks of major pollution accidents. Automatic Identification System (AIS) has improved the safety of navigation by monitoring the ships in real-time. The whole Baltic Sea has been covered by AIS since first of July in 2005 (HELCOM 2010b: 18).

The Baltic Sea is a particularly difficult sea area to navigate, much more difficult than many other areas in Europe (HELCOM 2010b: 20). This is due to many shallow water areas, narrow straights, large archipelagos, and especially challenging winter conditions. The problem of narrowness and shallowness can be seen, for example, in grounding statistics. Where 44 % of accidents in the Baltic were groundings in 2009 (EMSA 2010a: 34), the same figure for other EU waters was only 28 % (EMSA 2010a: 6). Correspondingly, the risk of collision is lower in the Baltic Sea than in world-wide operations. This is explained by the fact that the tankers in the Baltic Sea operate on short voyages and spend a major portion of the journey in waters with navigational risks whereas tankers in world-wide operations generally spend most of the time in open waters (HELCOM 1990: 5).

Winter trafficking is challenging because of the harsh weather conditions, especially because of ice cover. The drifting and ridging of the ice exposes ships to hull damages, as thick ice ridges are difficult to penetrate. Ships might also get stuck in the compressed ice fields (Hänninen & Rytkönen 2004: 26). The fact, that during wintertime it is dark almost round the clock, makes winter transportations even more difficult (Hänninen 2005: 9). Fluent shipping in ice conditions is still possible but it needs special means. Each country has its own instructions to ensure safe winter trafficking. For example, in Finland the Finnish Transport Agency is responsible for the winter navigation. Its Winter Navigation Department monitors icebreaking services, imposes traffic restrictions, and grants exemptions to vessels. Russia and Estonia have similar systems too (Hänninen & Rytkönen 2004: 27).

Ships are classified according to their ability to navigate in ice. The strongest vessels, classified as 1A and 1A super, are able to sail unassisted in most ice conditions. Weaker classes, 1B, 1C, and 2, are assisted by icebreakers or are towed. Ice classification is required for all the ships arriving or departing from Finnish or Swedish ports in the winter (FTA s.a./a). Despite of the difficulties originated from ice cover, the influence of winter is not seen very remarkably in the volumes of trafficking, at least not in the central part of the Gulf of Finland. High numbers of ships classified as 1A or 1A Super, may be one reason for this (Hänninen & Rytkönen 2004: 27).

2.2.3 Chemical transportation in the Baltic Sea

Both the number of chemicals and the volume of goods transported are constantly growing in the Baltic Sea. The number of different substances and compounds transported is counted in thousands. Nevertheless, the amount of oil transportations is still 10 to 20 times higher than the same of chemical transportations (Hänninen & Rytkönen 2006: 14–15). The most common chemicals transported in year 2004 were ammonia, acetone, ethylene glycol, phenol, phosphoric acid, methanol, sulphuric acid, styrene monomer and caustic soda (Hänninen & Rytkönen 2006: 28).

Chemical tankers operating in the Baltic Sea are generally in good shape (Hänninen & Rytkönen 2006: 15). According to Hänninen’s and Rytkönen’s (2006: 29) calculations, there are 43 companies in the Baltic Sea area that own or operate chemical tankers. This estimation contains also companies from Norway. These companies have about 500 vessels that carry chemicals. However, 78 % of the Baltic traffic is operated by three of the largest companies (Hänninen & Rytkönen 2006: 29). The shipping intensity of the chemicals is the highest in the south-western parts of the Baltic Sea and it is relatively high also in the Gulf of Finland (HELCOM 1990: figures 1–7). The main route to enter or leave the Baltic Sea is via Kiel Canal. The Danish Straits are used also but in lesser extent (HELCOM 1990: 3).

3 REVIEW OF PREVIOUS STUDIES AND EXISTING DATA ON TRANSPORTATION OF CHEMICALS IN THE BALTIC SEA

3.1 General overview

Chemical transportations have not been studied excessively in the Baltic Sea region. There are only a few comprehensive studies that cover the whole Baltic Sea area. Many of the studies are very general in nature or are more concentrated in the transport of oil and oil related substances. Some studies are published regularly, but they are concentrated on more detailed issues or limited areas. For example, the Ministry of Transport and Communication of Finland compiles a report every five years, but it handles transport of hazardous substances only from a Finnish point of view.

Generally, the whole shipping industry is growing rapidly in the Baltic Sea region, and also the amount of chemical transportations has increased significantly (Hänninen & Rytkönen 2006: 15). As time passes by, the relative importance of ports and chemicals may also change. All these mean that the data gets old very fast and new information is needed all the time. New pressures are set by the legislation and technology that have improved a lot in the shipping industry in the past decade. HELCOM report (1990: 14) suggests the information to be updated and reviewed at intervals of five years. The latest comprehensive study, *Transportation of liquid bulk chemicals by tankers in the Baltic Sea*, was published in 2006, but the data is from year 2004. Therefore, there really is a growing need for a new comprehensive study about maritime chemical transportations in the Baltic Sea.

3.2 Previous studies

3.2.1 Technical Research Centre of Finland

The most recent comprehensive study about transportation of chemicals in the Baltic Sea area was published by VTT, also Technical Research Centre of Finland, in 2006. The publication called ***Transportation of liquid bulk chemicals by tankers in the Baltic Sea*** was written by Hänninen and Rytkönen. The study contains large amounts of background information about the maritime chemical transportations, the Baltic Sea, laws and regulations, protection programmes, tankers types, accidents, and both properties and behaviour of chemicals. There is also a brief analysis of chemical outflow and spreading.

The main part of the study introduces statistics about liquid chemicals handled in the Baltic Sea ports in 2004. The publication is based on data gathered from public registers and information of port authorities and operators. They also executed a special questionnaire on transported bulk chemicals for the ports. However, Hänninen and Rytkönen (2006: 3) do not consider the data to be full and complete, because some of the ports were unwilling to share their statistics. The obvious reason for this is that operators find the information to be too sensitive to share.

According to the study, there are 46 ports in the Baltic Sea that handle some sorts of chemicals. Statistics of these ports are discussed one by one, some ports more closely than other. The ports are divided by countries in a following way: 16 ports in Finland, 13 in Sweden, 2 in Denmark, 2 in Germany, 4 in Poland, 1 in Lithuania, 2 in Latvia, 3 in Estonia and 3 in Russia. In Finland, chemicals are mostly handled in Hamina, Kotka, Pori, Oulu, and Sköldvik, and in Sweden mostly in Helsingborg, Skelleftehamn, Stenungsund, and Gävle (Hänninen & Rytkönen 2006: 43–67). The most common chemicals transported in the Baltic Sea were said to be ammonia, acetone, ethanol, ethylene glycol, phenol, phosphoric acid, methanol, sulphuric acid, styrene monomer and caustic soda (Hänninen & Rytkönen 2006: 68–69), but no numbers or quantities were given.

3.2.2 HELCOM

Another comprehensive study was published 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*** presents transportation data of chemicals in bulk in all Baltic Sea ports during the entire year of 1987. The data acquisition in this HELCOM study was executed with more specific and time-consuming means than the same in the VTT study from year 2004 (Hänninen & Rytkönen 2006: 3). In that way, this HELCOM report is, at least in some parts, the most comprehensive study about the subject still today. Nevertheless, it should not be forgotten that the data is more than twenty years old.

The main objectives of this study was to identify the transportation patterns for chemicals carried in bulk in the Baltic Sea and to identify the related risks for outflow and potential hazards to the marine environment. The study did not include liquid chemicals carried in packaged form, or solid chemical substances carried either in bulk or in packaged form. The estimated amount of chemicals carried per year within the Baltic Sea area totalled about 5.8 million tons of liquid chemicals and about 2.9 million tons of gases (HELCOM 1990: 1–3). The quantities of liquid chemicals are further divided into MARPOL categories of the time (table 3.1) (HELCOM 1990: table 1).

Table 3.1. Estimates of yearly transportation of chemicals in the Baltic Sea area by old MARPOL categories. (Modified from HELCOM 1990: table 1)

Category of chemical	**Quantity shipped (million tons/year)**
Category A	0.2
Category B	0.7
Category C	2.2
Category D	1.7
Sum A-D	4.8
Appendix III	1.0
Gases	2.9
Total	8.7

The most transported liquid chemicals in the Baltic Sea quantified by tons were methyl alcohol, sodium hydroxide solution (liquid caustic soda), pyrolysis gasoline, sulphuric acid, phosphoric acid, and xylene (figure 3.1). The most transported gases were ammonia, propane, butane, propylene, and vinyl chloride (figure 3.2). All of these substances were transported more than 100,000 tons. Furthermore, over a hundred other substances were transported in a lesser extend. (HELCOM 1990: table 2)

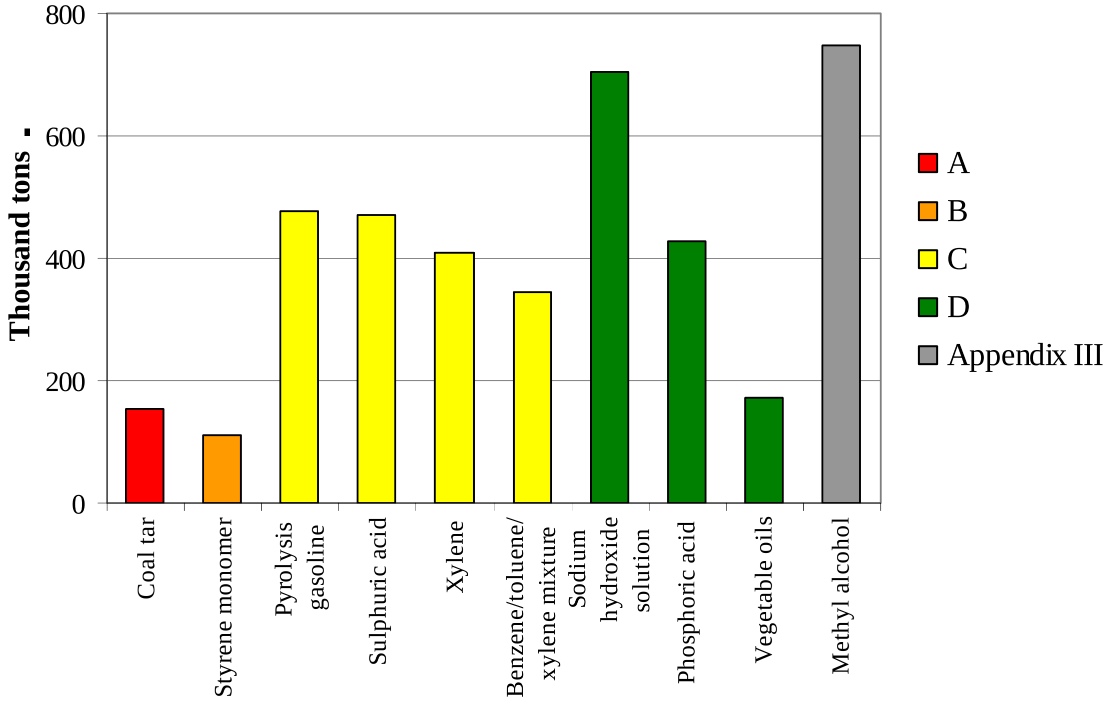

Figure 3.1. The most common liquid chemicals and their quantities transported in the Baltic Sea during the entire year of 1987. Categories A–D and Appendix III refers to the MARPOL classification of the time. (HELCOM 1990: table 2)

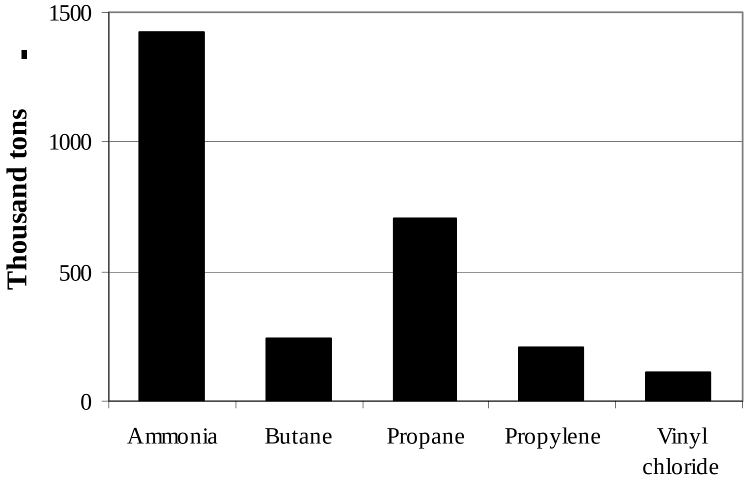

Figure 3.2. The most common gases and their quantities transported in the Baltic Sea during the entire year of 1987. (HELCOM 1990: table 2)

As a result, the report presents plenty of calculations and estimations concerning the expected number of accidents with outflow and their geographical distribution, the size of the significant outflow, the substances likely to constitute the highest risk for accidental outflow, and the related hazard to the marine environment (HELCOM 1990: 1). According to the study, the likely total number of accidents with outflow of chemicals was calculated to be 35 in 100 years. If these accidents are divided into the MARPOL categories of the time, there would be statistically one accident involving category A, three involving category B, 14 involving category C and 17 accidents involving category D cargoes (HELCOM 1990: 11–12).

The quantities of shipped liquid chemicals and gases were the highest in the southwestern part of the Baltic Sea. The further one goes from the Danish Straights the lesser the transported quantities were. However, there were more substances transported in the Gulf of Finland than in the Gulf of Bothnia. The relative environmental risk caused by transporting hazardous substances was also computed to all the shipping route segments. According to the calculations the highest risks were in the areas where the transportation quantities were also the highest. The risk was relatively high also in the Gulf of Finland. (HELCOM 1990: figure 6)

Another comprehensive study by HELCOM is called ***Study of the Transportation of Packaged Dangerous Goods by Sea in the Baltic Sea Area and Related Environmental Hazards***. The study was published in 1993 and it is based on data collected from all Baltic ports during October and November 1990. It contains information on both loading and unloading of packaged dangerous goods. A two months sampling period may be inadequate for obtaining a statistically reliable data, but it still gives a large amount of detailed and useful information about the subject. (HELCOM 1993: 1)

The total quantity of packaged dangerous goods handled in the Baltic Sea ports per month was calculated to be 143,000 tons and the number of individual parcels was about 11,400 respectively (HELCOM 1993: 3). The total number of substances shipped was 795, but more than half of these were shipped only once or twice per month. About 100 of these substances were shipped regularly, that is to say in 20 parcels or more per month. Regularly shipped substances account for about 75 % of all transported parcels. Furthermore, 50 % of parcels containing regularly shipped substances contain substances classified as marine pollutants or potential marine pollutants (HELCOM 1993: 7). The quantitatively most shipped substances were ammonium nitrate fertiliser, calcium carbide, paint, chlorine, resin solution and polystyrene beads (HELCOM 1993: table 7).

3.2.3 Ministry of Transport and Communications of Finland

The Finnish Ministry of Transport and Communications publishes a report that combines the Finnish statistics about transport of dangerous goods by sea, road, rail, and air. Reports are compiled every five years. The newest one, ***Transport of Hazardous Substances 2007***, was published in 2009 and contains data from the year 2007. The previous reports handle data from years 1987, 1992, 1997 and 2002 (Häkkinen 2009: 4). The statistics concerning the sea transportations are from the Finnish Maritime Administration. The data is based on administration's own statistics and information reported by the ports. Reports handle both bulk and packaged goods (Häkkinen 2009: 7).

According to the latest report, 2,852 thousand tonnes of bulk chemicals were transported by sea in Finland in year 2007. Since the same figure was 4,906 in year 2002, the amount of chemical transportation had decreased 42 % in five years. Three percent of all the liquid chemicals shipped in bulk were classified as category X in new MARPOL classification. 85 percent were classified as category Y chemicals and 12 percent as category Z chemicals, respectively. The chemicals handled the most in the ports were methanol, caustic soda, xylene, phosphoric acid, methyl *tert*-butyl ether, phenol and sulphuric acid (figure 3.3) (Häkkinen 2009: 34–35). Most of the chemicals on the list are the same that the chemicals transported the most already in year 2002 (Häkkinen 2004: table 12). The biggest difference is the lack of ethylene glycol from the list of 2007. Ethylene glycol was clearly the most common chemical handled in the Finnish ports in 2002.

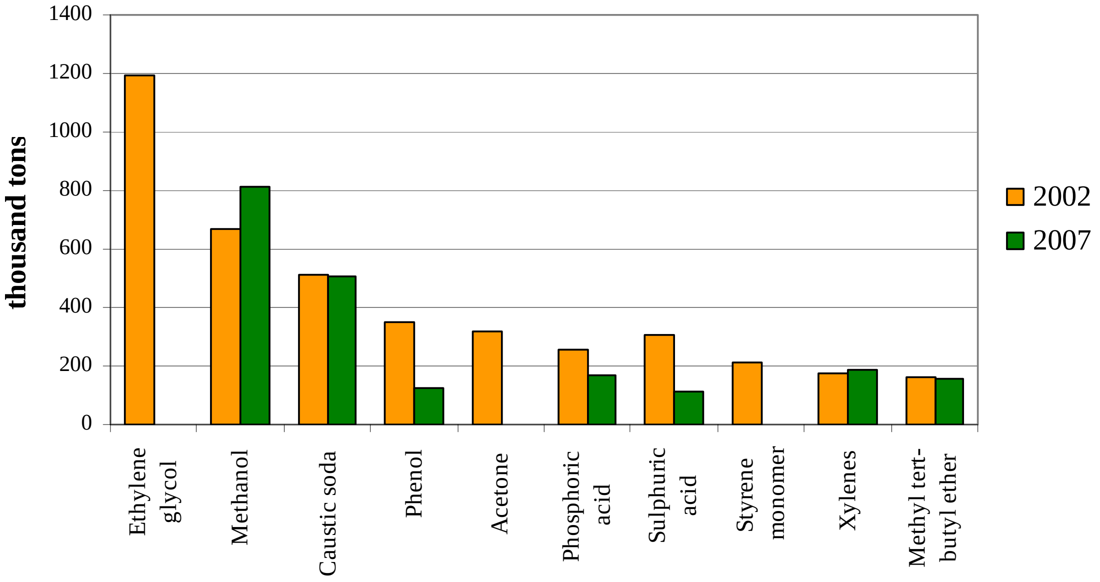

Figure 3.3. The chemicals handled the most in Finnish ports in years 2002 and 2007. (Häkkinen 2004: table 12; Häkkinen 2009: table 9)

Only three percent of all the maritime transportations from and to Finnish ports were categorised according to the IMDG code. The amount of exports and imports were almost equal. More than half of the goods were either flammable liquids (category 3) or corrosive substances (category 8) (figure 3.4). The absolute amount of goods in both these categories had increased in five years, but the relative importance of flammable liquids had decreased and corrosive substances increased. (Häkkinen 2004: table 14; Häkkinen 2009: 35–36)

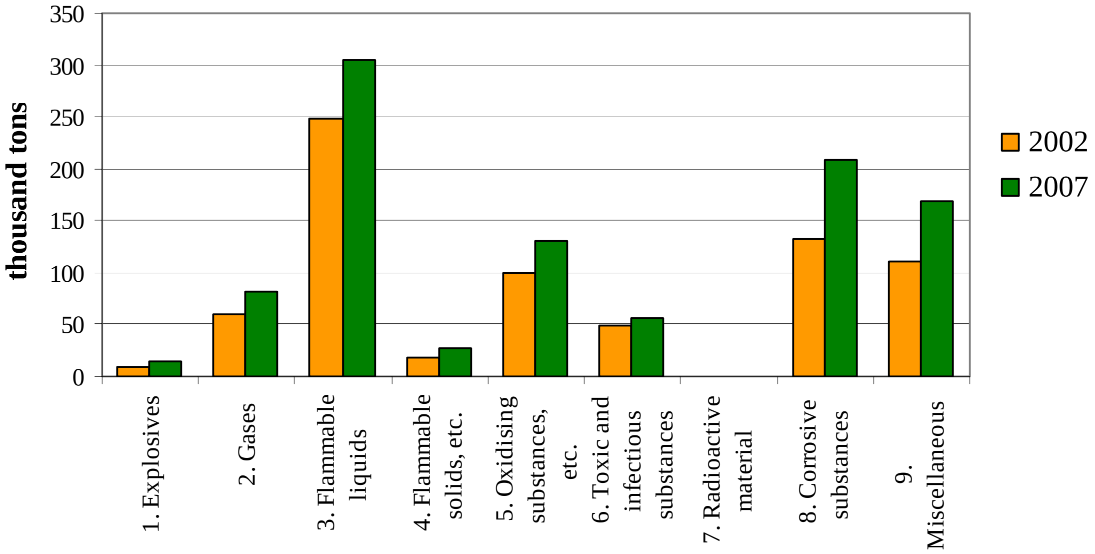

Figure 3.4. The packaged dangerous goods handled the most in Finnish ports in years 2002 and 2007. The goods are grouped according to the nine main classes of IMDG code. (Häkkinen 2004: table 13; Häkkinen 2009: table 10)

The biggest importing ports of hazardous substances in 2007 were Kilpilahti, Naantali, Pori and Helsinki, and the biggest exporting ports Kilpilahti and Hamina (Häkkinen 2009: 37). In 2002, the biggest importing ports were Kilpilahti, Naantali, Rautaruukki, Helsinki and Pori, and the biggest exporting ports Kilpilahti, Kotka, Hamina and Naantali (Häkkinen 2004: 40). However, many ports handle only certain type of substances on a large scale. For example, Naantali and Turku are important handlers of packaged hazardous goods, and Kotka and Hamina are more concentrated on liquid bulk transportation (table 3.2) (Häkkinen 2004: 41; Häkkinen 2009: 37–38).

Table 3.2. A list of the biggest importing and/or exporting ports of hazardous substances in Finland during years 2002 and 2007. (Häkkinen 2004: 41; Häkkinen 2009: 37–38)

	2002	**2007**
Gases	Hamina, Kilpilahti, Tornio, Uusikaupunki	Kilpilahti
Chemicals	Hamina, Kilpilahti, Kokkola, Kotka, Pietarsaari, Pori, Rauma, Uusikaupunki	Hamina, Kilpilahti, Kokkola, Kotka, Pietarsaari, Uusikaupunki
Cruel oil and oil products	Hamina, Kilpilahti, Naantali	Hamina, Kilpilahti, Naantali
Solid bulk	Helsinki, Inkoo, Kristiinankaupunki, Naantali, Pori, Rautaruukki, Vaasa	Helsinki, Pori, Raahe
IMDG	Helsinki, Naantali, Turku	Helsinki, Naantali, Turku

3.2.4 Turku School of Economics

Turku School of Economics operated a project called Safe and Reliable Transport Chains of **Da**ngerous **Go**ods in the **B**altic Sea Region, also DaGoB, during years 2006 and 2007. The project aimed at improving the co-operation between public and private stakeholders related to dangerous goods transport in the Baltic Sea Region by connecting the stakeholders on different levels, providing up-to-date information on cargo flows, supply chain efficiency and risks related to dangerous goods transport. (Suominen 2007: 9)

The project published more than ten reports or other publications in two years. In general, reports handle the subject of transport of dangerous goods in the Baltic Sea Region in very diverse way and from many perspectives. However, in many cases the reports do not concentrate only on maritime transport but also handle closely road, rail and air transportations. What should also be kept in mind is that the project started almost five years ago and the data in many of the reports is even older than that, usually from the beginning of the decade. As said earlier in this report, data about shipping gets old really fast. Thus DaGoB publications are not necessarily up-to-date information anymore.

Project's summary report ***Safe and Reliable Transport Chains of Dangerous Goods in the Baltic Sea Region*** lists key findings from all the research sectors of the project (Ojala *et al* 2007). Risks and incidents related to transport of dangerous goods are discussed in ***Maritime Transport and Risks of Packaged Dangerous Goods*** (Mullai 2006) and ***Dangerous Goods Related Incidents and Accidents in the Baltic Sea Region*** (Suominen & Suhonen 2007). ***Dangerous Goods Transport in the Baltic Sea Region: Authorities, Agencies and Regulations*** (Zetterström 2007) lists authorities who deal with road, rail and maritime transport of dangerous goods and their roles and responsibilities in the Baltic Sea region. The report handles these issues separately from Estonian, Finnish, German, Latvian, Lithuanian and Swedish point of view. And of course, there are also a few reports about the amounts of dangerous goods transported in the Baltic Sea Region. ***Transport of Dangerous Goods in the Baltic Sea Region*** (Suominen 2007) is very similar to the reports that the Ministry of Transport and Communications of Finland publishes every five years. However, in the DaGoB report there are also statistics from the other Baltic Sea countries beside Finland.

3.3 Existing databases

3.3.1 PortNet

PortNet is an information system for collecting notices required for ships arriving to or departing from a Finnish port. It is presently managed by the Finnish Transport Agency. PortNet has about 1,000 daily users and it lists about 40,000 port visits every year (FTA s.a./b). The main users of the information system are the port authorities, ship agents, stevedoring companies, maritime administration, customs, vessel traffic operators, and the frontier guard (SPC s.a.).

The PortNet system is operating only in Finland at the moment. Data as detailed as the one provided by the PortNet system is not available from the other Baltic Sea countries. Small case studies presented here contain therefore information only from Finnish ports. The first study concentrates on the content of the transportations. Because of large amounts of information available, only two example ports were selected. These are the ports of Hamina and Kotka that are both, according to Hänninen and Rytkönen (2006: 45), the greatest chemical handlers in Finland. The sample period was three months in the late summer and early autumn of year 2010 (1.7.–30.9.2010).

The PortNet provides data from dangerous cargo both in bulk and packaged form. Packaged goods are classified according to the IMDG code. During the three months time period cargoes handled in the ports of Hamina and Kotka contained mostly flammable gases (IMDG 2.1), flammable liquids (IMDG 3), toxic substances (IMDG 6.1), and corrosive substances (IMDG 8) (figure 3.5). The remaining categories constitute less than 20 % of the total amount of the packaged dangerous cargo.

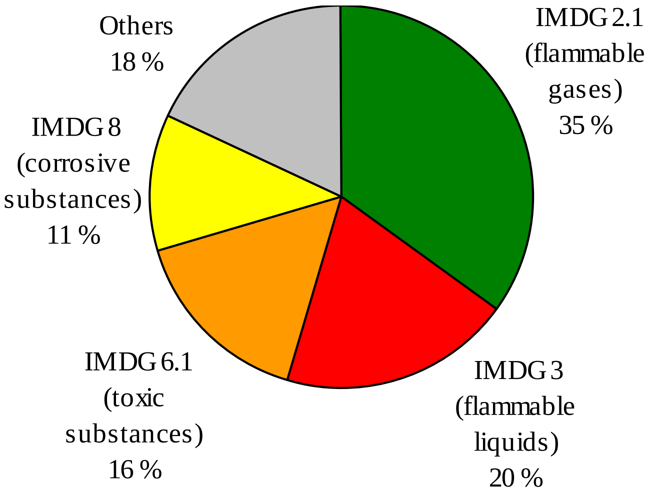

Figure 3.5. The packaged dangerous cargo handled the most in the ports of Hamina and Kotka in three months time (1.7.–30.9.2010). Substances are categorised according to IMDG classification. Data gathered from the PortNet service.

The total amount of bulk chemicals handled in the two ports in three months was 418,561 tonnes. 298,490 tonnes were handled in Hamina and 120.071 tonnes in Kotka. If estimated by weight, the majority of dangerous bulk goods were reported as chemicals, and only 7.4 % were gases. The most handled dangerous goods were methyl alcohol, *n*-pentane, xylenes, isopentane, methyl *tert*-butyl ether, *n*-paraffin, caustic soda and *n*-butanol (figure 3.6). These eight chemicals constituted over 93 % of all the chemicals handled in the ports of Hamina and Kotka.

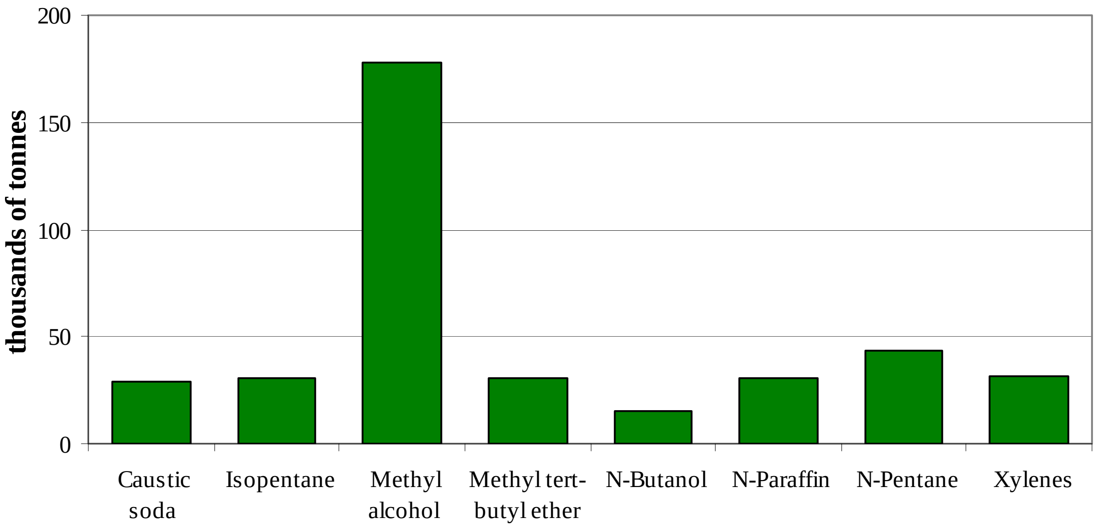

Figure 3.6. The dangerous bulk cargo handled the most in the ports of Kotka and Hamina in three months time (1.7.–30.9.2010). Data gathered from the PortNet service.

Chemicals are transported between Finland and other countries. Another small case study lists countries which have loaded or unloaded chemicals handled in the port of Kotka during entire year 2009. More than two thirds of the bulk chemicals handled in Kotka were imported to or exported from the Netherlands and Belgium (figure 3.7). Other important partners were China, United Kingdom, and Sweden. And, more than half of the IMDG transportations were imported to or exported from Germany. The three most important partners, Germany, the Netherlands, and Belgium, handled more than 95 percent of all the packaged dangerous goods loaded or unloaded in the port of Kotka. The transportations between two Finnish ports were not included in these numbers. Approximately two thirds of hazardous substances were transported by container ships, almost 20 percent by ro-ro ships, and only 15 percent by tankers in bulk form. However, this accounts only the number of chemicals shipments, not the quantity of the chemicals. Each ship can transport several different chemical at a time, which means that the number of chemical ships visited in the port of Kotka is less than a number of chemical shipments handled in the port.

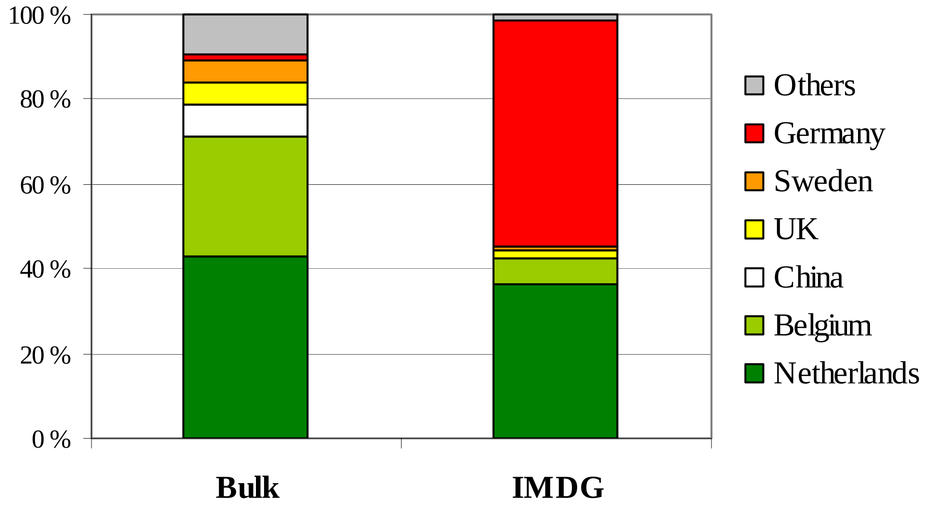

Figure 3.7. Countries that loaded or unloaded the chemicals handled in the port of Kotka during year 2009. Data gathered from the PortNet service.

PortNet offers plenty of useful information about the maritime chemical transportations. However, the usability of the data is somewhat poor from the researcher's point of view, as the data processing is quite time-consuming and laborious. Thus, the data management system needs to be improved. With better user interface the data would be easier to use, which would also increase the benefits gained out of it.

3.3.2 Eurostat

Eurostat is a statistics centre of the European Union. It provides statistical information at European level and promotes the harmonisation of statistical methods across the Europe. Most of the data collections are based on legislation applied by member states or candidate countries of the European Union and European Free Trade Association (EFTA). Some collections are also based on voluntary agreements (Eurostat 2010). Statistics contain both quarterly and annual data, and some statistics are also available at a regional level (NUTS 2, 1 and 0). There are information about gross weight of goods, vessel traffic and passenger movements (Eurostat 2009).

The maritime transport statistics are based on the terms of Directive 2009/42/EC of the European Parliament and of the Council on statistical returns in respect of carriage of goods and passengers by sea. And for example, the classification of cargo types has been established in conformity with the United Nation ECE Recommendation N°21 (Eurostat 2009). There are six types of cargo; liquid bulk, dry bulk, containers, self-propelled and non-self-propelled roll-on roll off, and other general cargo. These are all divided into several subtypes. For example, both bulk types have four subclasses (table 3.3) (Anon. 2009b).

Table 3.3. The type of cargo classification used by Eurostat in maritime transport statistics (Anon. 2009b)

Category	**Code, 1 digit**	**Code, 2 digits**	**Description**
Liquid bulk	1	1X	Liquid bulk goods
		11	Liquefied gas
		12	Crude oil
		13	Oil products
		19	Other liquid bulk goods
Dry bulk	2	2X	Dry bulk goods
		21	Ores
		22	Coal
		23	Agricultural products
		29	Other dry bulk goods

Eurostat data is available for all the Baltic Sea countries that are member states of the European Union. In practise, this refers to Finland, Sweden, Denmark, Germany, Poland, Estonia, Latvia and Lithuania. The only Baltic Sea country that is missing this kind of data is naturally Russia. Even bigger problem is that the cargo type classification does not include separate category for chemicals. For example, liquid chemicals belong to main category of liquid bulk goods that mostly consist of oil related substances. There is a separate subcategory for liquefied gases, but other liquid chemicals must belong to remaining category of other liquid bulk goods. Thus it is quite impossible to estimate the real amount of transported chemicals according to the EU statistics.

As a case study, a small sample of data from Eurostat has been analysed here. The sample includes data from all eight countries from which data is available. It covers quarterly statistics from year 2007 to year 2009. The category of liquid bulk goods has been chosen, since it most likely includes also chemical transports. The sample shows that liquefied gases and other liquid bulk goods are transported much less than crude oil and refine oil products (figure 3.8). In terms of absolute values, liquefied gases are mostly transported in Sweden (h), Latvia (g), and Germany (f) and other liquid bulk goods in Germany (f), Finland (b), and Sweden (h). In Lithuania (c), there was no transport of these two classes registered during three years time period. And the amounts were very minor in Estonia (e), too. In general, the transport of oil related liquids started to decrease at the beginning of year 2009. And conversely the transport of gases and other goods increased a little at the end of the year 2009.

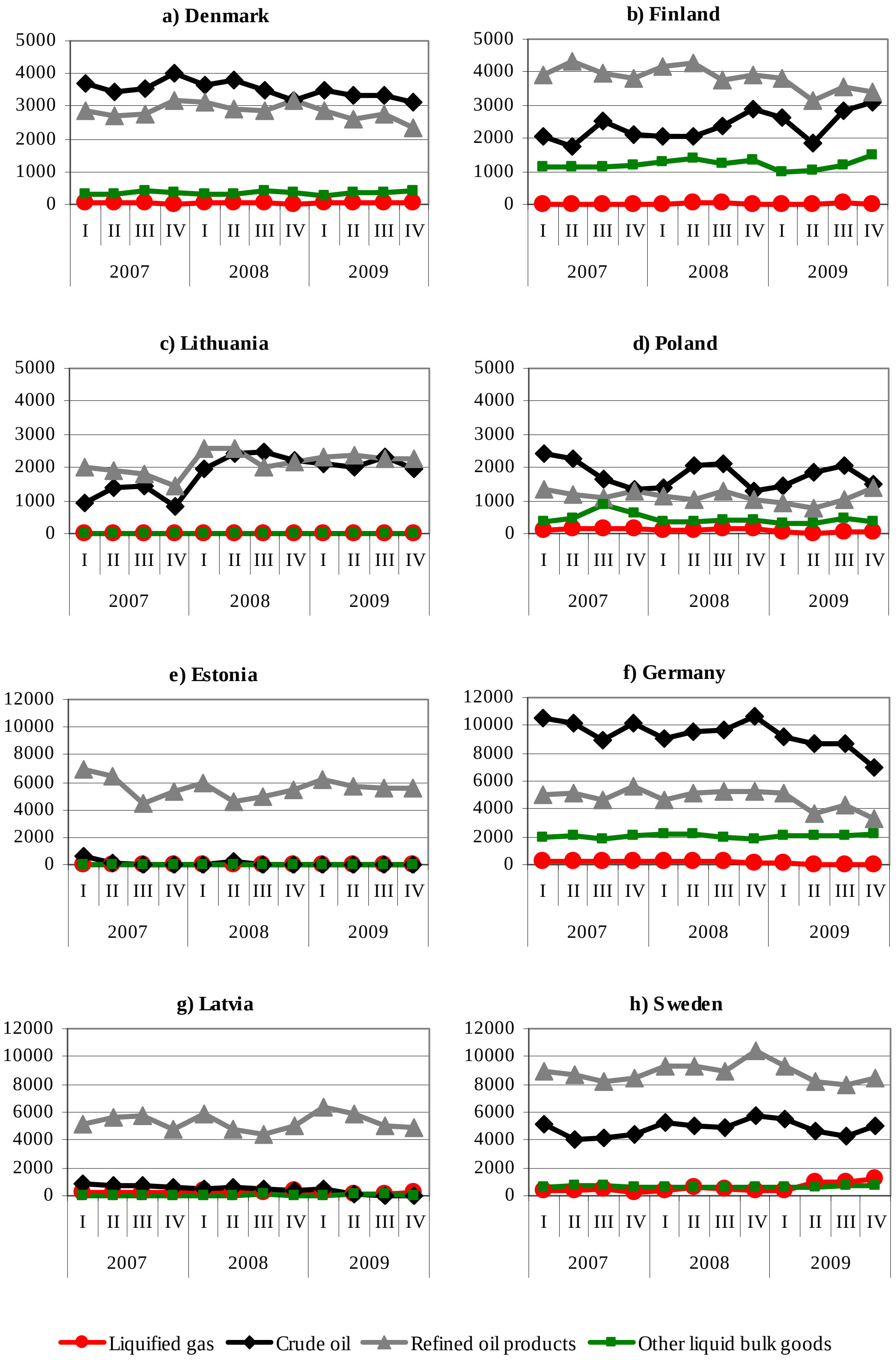

Figure 3.8. Maritime transport statistics of the Baltic Sea region's EU member countries. Quarterly data from years 2007–2009.Data in thousands of tonnes. Pay attention to different scales: from zero to 5,000 in graphs a–d; and from zero to 12,000 in graphs e–h. Data gathered from the Eurostat service.

3.3.3 National statistics from the Baltic Sea countries

Some Baltic Sea countries publish also their own national statistics about chemical transportations. But, as said earlier, these are not necessarily comparable with each other, as the classification systems differ between countries. The term chemicals may include different substances, chemicals may be divided in several subgroups or they may be grouped with other substances as a larger, more general main category. Many classifications group, for example, chemicals, oil products and other liquid bulk cargo in one single category. Moreover, incompatible datasets are not a problem just between the countries, but also within the countries, as partly overlapping datasets are being collected simultaneously by different organisations.

Also data availability became a problem in this review. Many countries distribute only limited amount of data and pre-defined publications free of charge. More detailed statistics are chargeable. Consequently, this report is based on free public data, and does not take a stance on availability or quality of restricted or chargeable data.

Finland

In Finland, the official maritime transport statistics are produced by the Information Services unit of the Finnish Maritime Administration that nowadays is a part of larger Finnish Transport Agency. The most essential parts of the statistics are available online free of change, but unpublished and more detailed data can be ordered directly from the Information Services. Some kind of statistics about foreign shipping had been published already since the middle of 19th century. However, fully comparable time series are available from year 1981 onwards. (FTA s.a./c)

All the information in the statistics of the foreign shipping traffic is gathered from the PortNet system. PortNet data is inspected and supplemented by the monthly reports of the port authorities. The classification system used in the official statistics of Finland has 16 commodity groups (FTA s.a./c). One of the 16 is a group called chemicals. There is data available on both exported and imported chemicals. And the statistics show that Finnish export rates of chemicals are somewhat higher than import rates (figure 3.9). Both export and import decreased a little from year 2008 to year 2009, but it seems that now in year 2010 they are again increasing back to the level of 2008 (FTA 2010).

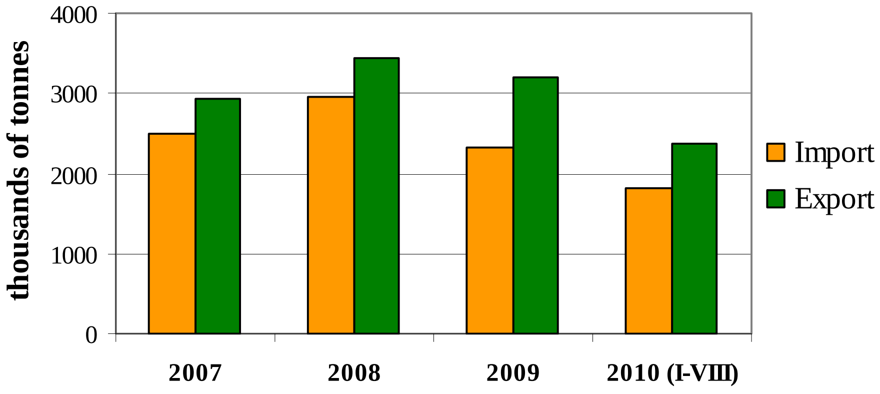

Figure 3.9. Shipping of chemicals between Finland and foreign countries. Full year data from years 2007, 2008 and 2009, and first eight months of year 2010. Data from the Finnish Transport Agency (2010)

Also Finnish Customs publishes foreign trade statistics. However, these statistics cover all the transport types, also the import and export by road, rail and air. Customs publishes statistics in diverse classification systems. The systems used are CPA2008, CPA2002, NACE rev. 2, TOL2008 and SITC. (Finnish Customs 2010b)

Sweden

In Sweden, Transport Analysis publishes country's official statistics about foreign trade. The classification system used in Sweden is NST 2007. One of its categories includes chemicals, chemical products and man-made fibres, rubber and plastic products, and nuclear fuel. New data is published quarterly and annually. The use of NST 2007 started in 2008. The data from years before that followed the classification system NST/R. Like in Finland, also in Sweden shipping declined in 2009, but the first half the year 2010 shows increasing trends both in import and export (figure 3.10). Swedish import rates are three to four times higher than export rates. (Transport Analysis 2010)

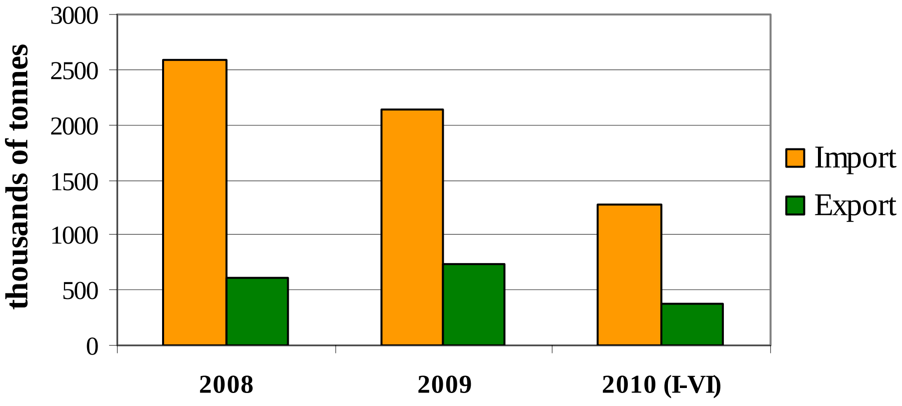

Figure 3.10. Shipping of chemicals between Sweden and foreign countries. The data includes cargo of chemicals, chemical products, man-made fibres, rubber and plastic products, and nuclear fuel. Full year data from years 2008 and 2009, and first six months of year 2010. Data from the Transport Analysis (2010)

Denmark

Danish shipping data is published by Statistics Denmark. There are both quarterly and annual data available free of charge. The type of cargo classification contains twenty categories, some example of which are liquid gas; liquid chemicals; solid chemicals; fertilisers; lime, cement, plaster etc.; crude oil and mineral oil products. Combined maritime import of liquid gases, liquid chemicals, and solid chemicals is around 300 thousand tonnes annually, and the export of the same substance groups is about half of that (figure 3.11). (Statistics Denmark 2010)

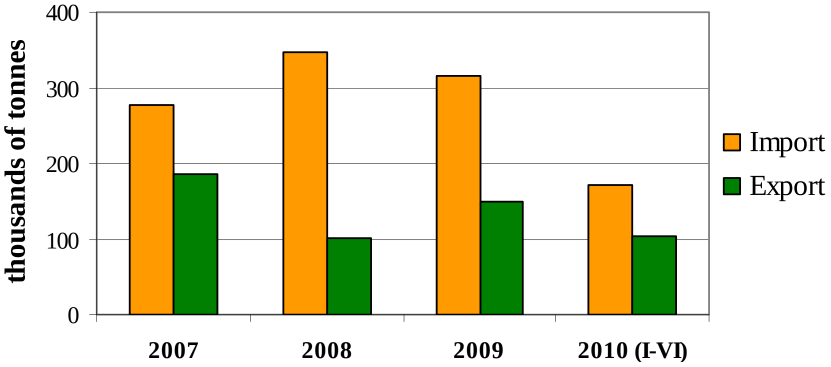

Figure 3.11. Shipping of chemicals between Denmark and foreign countries. The data includes cargo types of liquid gases, liquid chemicals and solid chemicals. Full year data from years 2007–2009, and first six months of year 2010. Data from the Statistics Denmark (2010)

Germany

Free of charge information available on the Federal Statistical Office of Germany is quite scarce. Product division of the cargo has ten categories, examples of these are chemical products and fertilisers. Maritime transport statistics were available in English only from year 2009. The quantity of chemicals carried by sea in year 2009 was 20,534 thousand tonnes. This is much more than in any other Baltic Sea country. (Federal Statistical Office s.a.)

Poland

There are no specific categories for chemicals or chemical products in the free of charge data of the Central Statistical Office of Poland. The maritime cargo types are divided into following groups: liquid bulk; dry bulk; large containers; ro-ro self propelled; ro-ro non-self-propelled and other general cargo. Thus, it is impossible to quantify Polish chemical shipping rates. To give some figures, liquid bulk goods were transported 12,797 thousand tonnes and dry bulk goods 19,207 thousand tonnes in year 2009. (Central Statistical Office of Poland 2010)

Estonia

The Statistics Estonia uses the same classification system, NST 2007, as Transport Analysis in Sweden. The system was changed after year 2008, so that comparable data is available only from years 2009 and 2010. The data from year 2000 to year 2008 was classified by the NST/R system. The export of chemicals and other products in the category number eight has been more than ten times higher than import in 2009 (figure 3.12). (Statistics Estonia 2010)

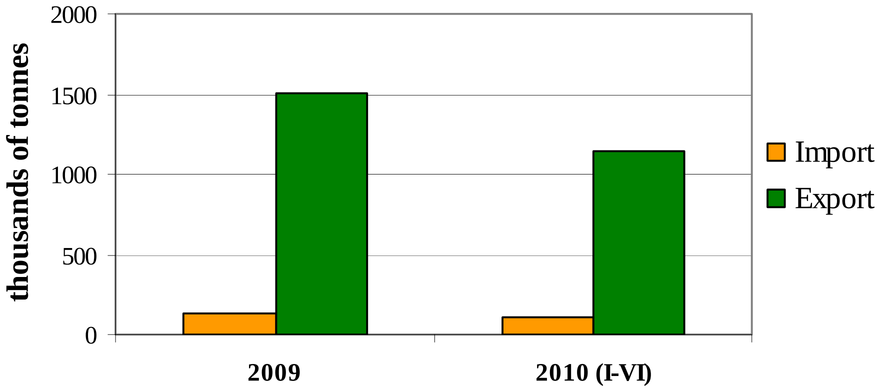

Figure 3.12. Shipping of chemicals between Estonia and foreign countries. Transit goods are included. The data includes cargo of chemicals, chemical products, man-made fibres, rubber and plastic products, and nuclear fuel. Full year data from year 2009, and first six months of year 2010. Data from the Statistics Estonia (2010)

Latvia

The Central Statistical Bureau of Latvia publishes annually statistics about cargoes loaded and unloaded in Latvian ports. The data is roughly classified by type of commodity. Chemicals are divided into groups of dry chemicals and liquid chemicals. Most of the chemicals are dry bulk (figure 3.13). However, there is only data about export of chemicals (Central Statistical Bureau of Latvia 2010). Apparently, there is no import of chemicals to Latvia. Latvia is the main transit route through the Baltic Sea region (Hänninen & Rytkönen 2006: 62), so that the proportion of transit cargo is quite high in Latvian ports.

Figure 3.13. Export of liquid and dry chemicals from Latvia to foreign countries. There was no reported import to Latvia. Data from the Central Statistical Bureau of Latvia (2010)

Lithuania

Statistics Lithuania uses CN classification as a basis in its pre-defined, free of charge information about chemical transports. The main section VI of the CN system includes products of chemical or allied industries. The abundance of the shipped goods is expressed as its value in the local current, Lithuanian litai. For example, in year 2009 imported chemicals constituted 9.1 % of the total value of import in that year. The same proportion for exported chemicals was 12.3 %. In more detailed level, there are 11 subsections of chemicals. The most imported groups were pharmaceutical products, organic chemicals, and miscellaneous chemical products and the most exported groups were fertilisers, pharmaceutical products, and miscellaneous chemical products (figure 3.14). Statistics Lithuania uses also NST 2007 classification in some of its statistics. (Statistics Lithuania 2010)

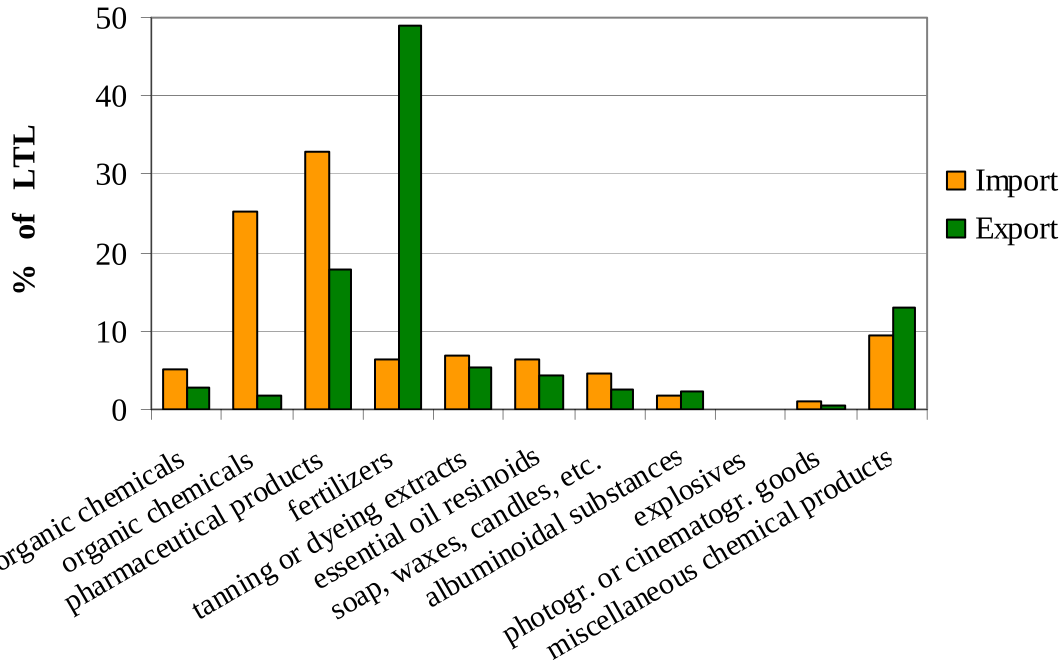

Figure 3.14. Shipping of chemicals between Lithuania and foreign countries. Products of chemical or allied industries divided into 11 subsections of the CN classification. The figures show how many percent that certain group of chemicals constitute of the total monetary value of all the chemicals imported to or exported from Lithuania. Data from the Statistics Lithuania (2010)

Russia

The Federal State Statistics Service of Russia (s.a.) shared only a very limited amount of data available for everyone. The data about transports were very general in nature, and gave no categorised information about different cargo types. According to Hänninen and Rytkönen (2006: 66–67) chemicals are handled in ports of St. Petersburg, Vyborg and Kaliningrad. However, Russian transhipments have an impact on port operations in other Baltic Sea countries too.

4 CHEMICAL ACCIDENTS AND INCIDENTS IN THE MARINE ENVIRONMENT

4.1 The risks related to the chemical accident in the marine environment

When comparing the differences and seriousness of chemical and oil accidents, there are several opinions and factors to be taken into account. First of all, risks related to possible oil accidents are easier to identify than risks caused by other kind of hazardous substances. There is such a great amount of different chemicals transported in the seas and oceans of the world. The problem is that many of these chemicals, chemical compounds, and other substances have different kinds of risk profiles and potentials (Malmsten 2001: 206). Secondly, a spill from a chemical tanker is usually smaller than a spill from an oil tanker, because chemicals are usually transported in lesser quantities. Chemical tankers are divided into small compartments, which further decreases the size of potential spills (Hänninen & Rytkönen 2006: 113). Nevertheless, chemical releases are said to be potentially more hazardous, because they are usually not as easily visible on the sea surface as oil spills (ITOPF s.a.). Also public safety risks are more severe in chemical releases (EMSA 2007: 5). All in all, according to Hänninen and Rytkönen (2006: 113) the released amount of chemicals is usually not large enough to lead to any significant damage.

It is very important to remember that many chemicals behave in very different way when spilled in water than on land. Some chemicals spread out quicker in water than on land, and thus may create a substantially larger hazard zone (Parfomak & Frittelli 2005: 9). Also the physical state of the released chemical may have an influence on the size of the area that is affected by the accident. The risk area is the smallest in a case of solid chemicals and the largest in a case of gaseous chemicals (figure 4.1). The risk area refers to the area around the spill where deaths, injuries, or other harmful incident may happen. The evaporation of a solid chemical is usually so low that the risk area is small but gases spread out easily and more rapidly (Malmsten 2001: 40–41).

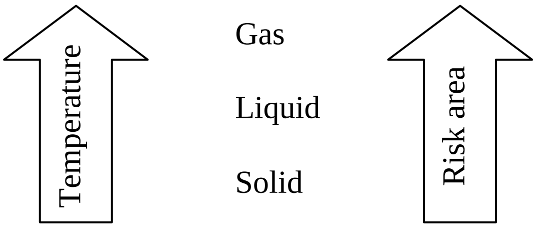

Figure 4.1. Physical state of a chemical is affected by temperature and it affects the size of a risk area around the spill. (Modified from Malmsten 2001: figure 2.3.4a)

Risks related to chemical incidents can mainly be divided into two types. These are the risks that affect human health (crew, intervening personnel and local populations) and the risks that affect environment. Risks related to human health are mainly caused by reactive substances (Bonn Agreement 2000). Explosions and fires are dangerous as such, but toxicity, corrosivity, radioactivity, etc, of chemicals make the problems even worse. The exposure to gases, fumes and particles of one chemical or mix of several chemicals happens mainly via respiration (VTT s.a.).

Hazards to the environment are varied and impacts can be long-lasting. Discharges can lead to mortality or infertility of certain species, contamination of coastlines, and water masses, disturbances to local amenities, etc (Bucas & Saliot 2002). Most shipping accidents have local impact on the environment, for example by polluting the shoreline in a certain area, but accidents may have also wider effects. This can happen via affecting components of the ecosystem that are significant for the whole region. For example, habitats, spawning grounds, or wintering birds are this kind of key components. Furthermore, the environmental effects of a spill depend greatly on the time and place of the spill and also other factors. This means that different spills of the same size can also have tremendously different effects on the environment. Therefore, from the ecosystem's point of view accidents should be evaluated according to their environmental effects instead of their size (HELCOM 2006: 14). At least in the case of oil spills, environmental impacts closer to the shore are easier to observe and monitor than impacts offshore. However, the latter are easier to quantify. For example, only a fraction of all casualties among the wildlife is from open waters. Marine mammals are usually less impacted (HELCOM 2010b: 26).

Sometimes chemical accidents have also socioeconomical impacts. The commercial value of marketed fishes may decrease if sublethal effects of chemicals affect the growth or appearance of the fishes. In the worst case the bioaccumulation of chemicals may stop the fishing and aquaculture entirely. The amenity value of the area can also decrease. The recreational use of the beaches and waters may be stopped entirely by a contamination of the areas or partly by a negative impact of an accident to the image and reputation of the area. (EMSA 2007: 42)

The impacts of a release depend on the behaviour of the chemical or chemicals in question. For example, the environmental harmfulness is highly affected by the persistence of a chemical. Chemicals that disperse quickly do not reach far but highly persistent chemicals have time to spread and accumulate to wider areas (Riihimäki et al. 2005: 60). The Bonn Agreement (2006) has identified nine potential hazards that can occur when a hazardous substance is released into water. Some of them are hazardous only to human health or marine environment and some are hazardous to both of them (table 4.1).

Table 4.1. Potential hazards that can occur when a hazardous substance enters into the marine environment. Behaviour categories: G = gases, E = evaporators, F = floaters, D = dissolvers, and S = sinkers. (Modified from Bonn Agreement 2006)

Potential hazard	**Behaviour category**	**Human health**	**Marine environment**
Toxicity by inhalation	G/E/F	x	
Explosiveness	G/E	x	
Flammability	G/E/F	x	
Radioactivity	G/E/F/D/S	x	x
Corrosiveness	G/E/F/D/S	x	x
Carcinogenicity	G/E/F/D/S	x	x
Aquatic toxicity	D/S		x
Bioaccumulation	D/S		x
Persistence	D/S		x

Malmsten (2001: 207) states that the type of maritime transportation, i.e. bulk or packaged, has a great influence on impacts of possible accidents. In a case of an accident, impacts on environment are generally smaller when the chemicals are transported in packaged form. However, the risk of an accident might be in that case bigger, because there are more things that can go wrong. Malmsten lists examples like incorrectly reported content, inadequate packaging, improper loading, etc. If one compares the risks of chemical transportations to the risks of oil transportations, the risk of accident is smaller in the former case. As said earlier, chemicals are often transported in parcel tankers. If only one parcel of that kind of ship breaks, the amount of hazardous substance delivered into the sea is much smaller than if a large single tank vessel would have been in the same accident (Hänninen & Rytkönen 2006: 77).

Harmfulness of substances is tested in many ways. For example, toxicity can be divided into acute and chronic toxicity, reproductive toxicity, carcinogenicity, etc. And the tests are usually carried with fishes, algae or water fleas (VTT s.a.). Information about the toxicity of chemicals can be found from several databases. For example, Hazardous Substances Data Bank (HSDB) contains comprehensive, peer-reviewed toxicology data for about 5,000 chemicals (HSDS 2009). Also substances considered as non pollutants can lead to hazardous outcomes. For instance, vegetable oils and some food products, like wheat, can cause serious problems to environment (Bonn Agreement 2000). Actually, vegetable oils can be much more dangerous to birds than crude oil, because vegetable oil slicks are often colourless and those have only a slight odour. Therefore, birds may be unable to detect slicks and get more easily oiled (Bucas & Saliot 2002).

According to Hänninen and Rytkönen (2006: 87) casualties involving chemical tankers can be classified into four classes. In the open sea, chemicals have more space to spread, dissolve or vaporise, which could lesser the negative impacts of the spill. However, it takes also longer time the rescue team to arrive, and sometimes the weather conditions are really challenging. The casualty happened close to shorelines of archipelagos can be easier to handle and reach, but environmental impacts may be more hazardous. The third scenario is a casualty that happens in a closed area, like in a harbour or in a terminal area. In these cases the spill is usually localised and restricted effectively. However, toxicity levels may rise very high in a restricted area. And, there is also an increased risk for health of the employees working in the area.

The fourth possibility is a casualty during winter in the presence of ice and snow (Hänninen & Rytkönen 2006: 87). The coldness and ice cover changes the properties of the chemicals in water. Hazardous impacts of chemicals may multiply in the cold environment, because the decomposition of the chemicals becomes slower. Thus chemicals may be drifted to larger areas. They may also accumulate to the adipose tissues of animals, which decreases the probabilities of the animal to survive beyond winter. The viscosity of the chemicals may change in cold too. The changes in the properties of the chemicals affect also the rescue operations possible to execute (Riihimäki et al. 2005: 60).

4.2 Chemical pollution response in the Baltic Sea

Hazardous substances are commonly transported in the Baltic Sea waters. For example, in a case study of HELCOM from year 1990 about 50 percent of all the parcels of packages dangerous goods contained marine pollutants or potential marine pollutants. The number of marine pollutants was identified by the UN numbers of the substances according to the IMDG code (HELCOM 1993: 24). The risk of chemical accident is high in the areas where the transportation rates are high as well. In the Baltic Sea the riskiest areas are in the south-western part of the sea and also the Gulf of Finland (HELCOM 1990: figure 11).

Physical and chemical properties of substances involved in an accident need to be defined before the selection of the appropriate response actions. Different specialised knowledge and operational expertise are needed in a response to a chemical release than to an oil spill. In all the marine accidents human safety has the highest priority. EMSA strongly recommends that no other response action than isolating the vessel should be taken until a risk assessment has been carried out. The risk assessment should consider environmental impacts and damage to socioeconomic resources as these may be more severe in chemical accidents than in oil accidents. Some examples of release response options are listed in the EMSA's action plan that considers the pollution preparedness and response of hazardous and noxious substances (table 4.2). (EMSA 2007: 49–50)

Table 4.2. Examples of response options to release of hazardous substances. (For more detailed description of the response actions, look EMSA 2007) (Modified from EMSA 2007: table 5.9)

Substance type	**Response option**
Toxic gas or smoke plume	Changing position of vessel
Substance that has a wide risk area	Towing vessel to less vulnerable area
Packaged goods	Ship to Ship Transfer
Bulk liquid cargoes	Ship to Ship Transfer
Gas, evaporator or dissolver that is not an environmental pollutant	Controlled release with dilution
Gas	Controlled release with sprinkler system
Evaporators, gas, dissolvers (floaters or sinkers, only if can be destroyed by action)	Destruction of ship and/or cargo
Floaters, floating packages, sinkers and wreck	Monitoring, survey and inspection
Floaters	Use of oil spill response techniques
Acids or bases	Neutralisation
Sinkers	Airlift dredge
Sinkers	Capping

The list of operational guides and manuals concerning the issues of chemical releases and pollution response is quite long. These have been published by several international and regional organisations, such as IMO and HELCOM. The manual of IMO was developed already in the 1990's. It consists of two sections that aim to provide guidance to governments in the field of chemical pollution response. The sections deal with spills of hazardous substances and packaged goods lost at sea. The 2nd Volume of the HELCOM Response Manual was developed in 2002. It can be used by the countries of the Baltic Sea region in operational co-operation, surveillance activities and combating exercises

(EMSA 2007: 17–19). Also national response manuals are possible. For example, the manual of Swedish Coast Guard (2009) is very detailed and comprehensive in nature.

Baltic Sea countries have their own authorities that are responsible for the response action if hazardous substances are spilled into water in their national waters. For example, the Finnish Environment Institute (FEI, or *in Finnish* SYKE) is the competent governmental pollution response authority of Finland whenever the pollution happens at open sea. The Finnish Defence Forces, the Finnish Border Guard, government owned company Meritaito Oy, and other organisations or groups may also participate in response actions if needed. Their part is to offer recourses like personnel, ships, and other material that helps in response actions (FEI 2010b). In Sweden the principal response authority in cases of marine spillages is the Swedish Coast Guard. Help and counselling is given by for example the Swedish Environmental Protect Agency, which is also responsible for the monitoring of the environmental impacts after the response activity (Kulander et al. 2004: 15).

The recovery of released hazardous substances may differ significantly from the recovery of an oil spill. Thus it is often impossible to use commonly available recovery tools and techniques designed for oil spills (EMSA 2007: 12). Response to chemical incidents requires both specialised personnel and equipment. For example, only special gas-tight vessels are capable of operating in hazardous atmosphere. These kinds of multipurpose vessels can be used in actions like discharging and recovering chemicals or in firefighting. Monitoring, detection, recovery, protection, and storage devices can be either onboard or easily deployable from predefined national stockpiles (EMSA 2007: 57–59).

The coldness and ice cover may create further problems to the recovery action in the Baltic Sea in the winter. For example, the viscosity of the chemicals may change in cold. In consequence, collecting techniques based on fluid-like masses are no longer effective if fluids change to act more like pseodoplastic solid masses. On the other hand, it is difficult for the recovery fleet to operate if surrounded by ice and snow. If chemicals are spread under the ice cover, the detection of the spill is more difficult and the use of dispersing agents is ineffective. However, ice breakers may be used to break the ice cover and to improve the mixing of chemicals with larger water masses. (Hänninen & Rytkönen 2006: 89)

4.3 Chemical accidents in the Baltic Sea region

The phase out of single hull tankers, stricter legislation, and new technical equipments has reduced the number of large scale oil and chemical spills during the last decades. According to Hänninen and Rytkönen (2006: 4) around 80 % of all incidents and accidents are due to the human factor. For example, human/machine interaction and cultural behaviour are causes of problems. Human factor can be divided into two categories. Truly human errors are falling asleep, making poor judgements, or being careless. On the other side, there are organizational errors, such as conflicting instructions, exert pressure, or poor communication (Mason et al. 1995: 2).

European Maritime Safety Agency (EMSA) states that 75 ships of all the ships navigating in the Baltic Sea were involved in accidents during year 2009. This includes sinkings (3 accidents), groundings (33), collisions (24), fires and explosions (10) and other types of accidents (5) (EMSA 2010a: 34). However, according to HELCOM (s.a.) statistics, there were as many as 105 accidents. Ten of these accidents resulted in pollution (figure 4.2), but in all the cases the cargo in question was oil. During the previous five years there have been 628 accidents, and 41 of these resulted in pollution. However, only in one case the polluting substance was reported to be a chemical, as in 2007 potassium chloride was released into sea. In all the other cases the polluting substance was categorised as oil or unidentified.

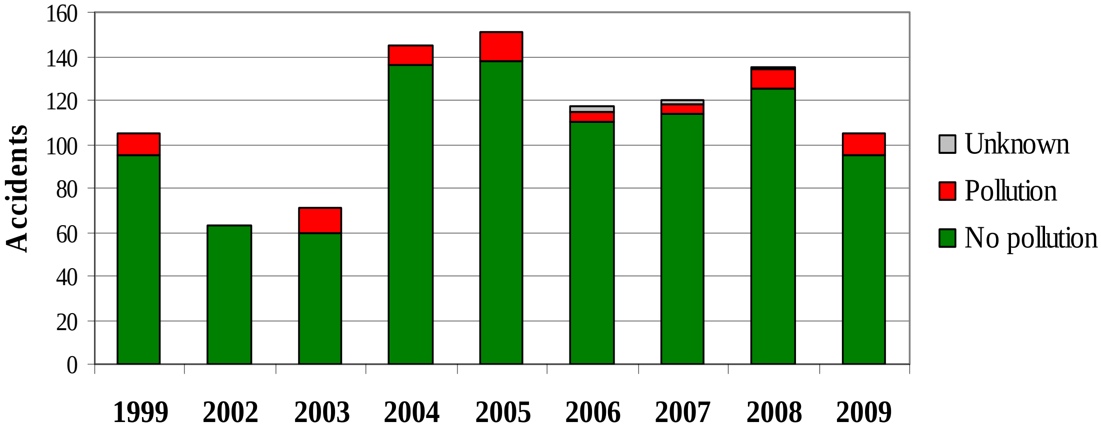

Figure 4.2.Number of accidents in the Baltic Sea during years 1999–2009. Only a small proportion of accidents results in pollution. Data from HELCOM (s.a.)

There have been only a few major accidents in the region recently, so some of the examples are over thirty years old. This does not take away the valuable lessons that the incidents can teach us. The accidents are divided into two types: human error related and machine breakdowns and other technical problems. Human errors are further divided into two subtypes. The first one includes improper handling of cargo and the second one navigational errors and inadequate supervision of processes like loading and unloading of cargo.

Improper handling of the cargo

As said, the most of the accidents are due to human error. For example, improper use of equipments or even use of wrong kinds of equipments is a potential cause of problems. It should be always kept in mind that different chemicals may have different properties, and thus they can not be handled in the same way. The equipment used in handling the chemicals should be compatible with the chemical in question. For example, in January 1976, a Belgian tanker **René 16** was unloading ammonia in the port of Landkrona in southern Sweden. The ammonia was pumped through a rubber hose that suddenly ruptured with a loud bang. 180 tonnes of ammonia leaked onto the quay and into the water. Furthermore, two members of the crew died in the accident. The hose used in unloading was intended for propane and butane instead of ammonia. Ammonia is corrosive, which is why the inside of the hose had been partially destroyed. Thus it can be said that improper equipment was the main reason for the accident (HELCOM 2003: annex 3). Ammonia is commonly transported and very widely used chemical. Releases of ammonia present different characteristics according to the physical storage conditions and the type of spill. Ammonia can be highly toxic to both human and the environment. The spill of ammonia can also create an oxygen demand into water (HSDB 2009).

In another example, a cargo ship **Julie A** was moored in the port of Aarhus in Denmark in November 1989. She had a leak in a tank that contained 300 tonnes of hydrochloric acid 33 %. It is a highly corrosive chemical that can react with iron and form flammable gas. It was found out that the internal coating of the tank was not resistant enough to the substance. There was a 25 mm hole in the tank, which was plugged by a response team. The spill response was carried out successfully and the pollutant was pumped out of the ship. However, this incident showed that the equipment used to transport hazardous substances must be compatible with the risks presented by the cargo (Cedre 2010). Hydrochloric acid can locally decrease the PH of the aquatic environment when spilled in water. The effect of acid on the organisms depends on the buffer capacity of the ecosystem (HSDB 2009).

Also improper storing of chemicals and stacking of containers have caused accidents in the Baltic Sea. For example, in July 1971, there were series of explosion in a Danish tanker **Poona** that was loading cargo in the port of Gothenburg. Due to some misfortunes in the ship chemicals got to react with each other. The result was that three sailors were killed and six injured. And it took ten days to fully extinguish the fire in the accident scene. The main mistake here was that an oxidizer and a combustible were stowed in the same hold. In this case, sodium chlorate and rapeseed oil reacted violently, making a flammable and explosive mixture. Furthermore, the sodium chlorate was decomposed to free oxygen, because of the heat of the fire. This decomposition is an exothermic and explosive chemical reaction (Cedre 2010). Sodium chlorate is toxic to aquatic organisms (OVA 2009).

During the recent years there have been two accidents, where stacks of containers have collapsed. Both accidents happened at the Baltic Proper. In February 2007, a stack of seven containers collapsed and damaged in a British container ship **Annabella**. The ship had pitched intensively because of heavy weather. The upper three of the containers contained butylene gas. The damaged hazardous containers were safely unloaded in the port of Kotka, where the ship was redirected (Cedre 2010). Three years later four containers collapsed in a Finnish cargo ship **Linda**. The bottom container in a stack broke, and three containers on the top fell into the sea and were lost (Cedre 2010). The crew noticed the incident twenty minutes after it happened. The exact location of the containers is uncertain, but they probably lie in 70 to 80 meters deep on the bottom of the sea YLE 2010). The content of the missing containers was uncertain too. According to Cedre (2010) one of the containers was transporting 5 tonnes of flammable substances and two others contained around 15 tonnes of marine pollutants. Other vessels passing through the area were warned by authorities. The accident happened on 6th of February 2010. The investigations about it are still ongoing by Accident Investigation Board of Finland (AIBF 2010). In both cases the bottom container in a stack collapsed under the weight of the others. And at least in Annabella accident, the maximum allowable stack weight of the bottom container had been exceeded. Shortcomings in the flow of information between the shippers, planners, the loading terminal, and the crew can result in accidents like this (Cedre 2010).

Inadequate supervision and navigational errors

Also navigational errors and inadequate supervision are human errors, but they are not directly related to the handling of chemicals. Instead the problem is more related to the attitudes towards safety regulations and navigation in general. The consequences of a major chemical catastrophe are way too appalling to be bypassed with disregard. The case of an Italian chemical tanker **Crystal Bubino** is one example of certain negligence. The tanker was loading nonylphenol ethoxylate in the port of Hamina in July 2000. The loading process was not supervised properly and the cargo overflowed to the sea. At least two tonnes of noxious chemical ended up in the sea and started to foam (AIBF 2000: 44). Reasons for the accident were insufficient competence of the mate supervising the loading, improper directions to the deck, and incomplete safety inspection of the loading equipment. For example, the safety checklist had been ticked by the chief officer without the relevant items being physically checked (AIBF 2000: 59). Nonylphenol ethoxylate behaves as a sinker and dissolver. Thus it was impossible to gather it from the sea (Hänninen & Rytkönen 2006: 30). Nonylphenol ethoxylate degrades readily to even more harmful substance, nonylphenol. The substances are very toxic to fish and other marine organisms, and it is also a hormone disrupting substance that mimics oestrogen (EA 2010). Consequently, fishes started to die soon after the overflow and rose to the surface. The seagulls that ate the dead fish probably suffered from reproduction problems the following spring (Hänninen & Rytkönen 2006: 30). Bioconcentration, bioaccumulation, and persistence of nonylphenol are high. Thus it is possible that the substances could be transported significant distances (EA 2010).

In October 1993 a German dry bulk carrier **Frank Michael** grounded due to a navigational error north of the Swedish island of Gotland. The vessel obtained severe bottom damage and the cargo of 1,100 tonnes of fertiliser started to leak. Responsible Swedish agencies started to debate about the need of recovery actions. The main point in the argument was the fact, that millions of tonnes of similar chemicals are emitted into the Baltic Sea every year. The cargo content of 1,100 tonnes was relatively minor compared to the other emissions. The final result was that no action was taken and the phosphate escaped into the sea during a few weeks after the accident. (HELCOM 2003: annex 3)

Ships transporting chemicals have also been involved in several collisions in the Baltic Sea. For example, the gas carrier **Mundogas Oslo** collided with another ship in the Bothnian Sea in October 1966. Due to the collision the Mundogas Oslo listed heavily and submerged partially. The ship was carrying 2,000 tonnes of liquid ammonia. Three and half months later it sank 64 meters deep. Since the accident, there have been chronic leaks of ammonia from the wreck and more than half of the cargo is believed to have been released into the sea. It is said, that Mundogas Oslo is the only gas carrier to have sunk due to a collision so far (Cedre 2010). Human lives were lost in the accident of a Liberian chemical tanker **Martina** in Northern Öresund. The collision happened in March 2000. Due to the very bad weather, the ship was impossible to reach for two days. Only two out of seven crew members were saved, and the cargo of 600 tonnes of 30 % hydrochloric acid were released into the sea. No harm was done to the environment by the release (Cedre 2010). The collision and sinking of a Chinese bulk carrier **Fu Shan Hai** happened between Sweden and Denmark, north off the island Bornholm in May of 2003. The main attention was targeted at an oil pollution caused by the accident, but the incident involved also 66,000 tonnes of potash that the ship was carrying at the moment of collision (Cedre 2010). The term potash includes group of chemicals that are mainly used as fertilisers (HSDB 2009).

Machine breakdowns and other technical problems

However, it should be remembered that not all the accident are caused by human errors. The engines and other machines may break, either onboard or at the quays. People dealing with chemicals should be prepared for these kinds of accidents too. For example, in January 2007 Cypriot bulk carrier **Golden Sky** had engine problems. The main engine could not develop full power for more than three days. Eventually, the ship grounded close to shoreline of Latvia, because of very bad weather (DMA 2008). The ship was carrying 24,983 tonnes of potash (Cedre 2010). However, the main problem was related to fuel oil that was spilled from the ship and formed a 40 km oil slick. The spill led to a substantial pollution on the coastline (EMSA 2008: 21–22). All the fuels and lubricants were successfully removed from the ship and 9,000 tonnes of potash were recovered and transhipped into barges. The ship was refloated and towed to the port of Ventspils, but it never operated again. All in all, the operations lasted four months (Cedre 2010).

A cistern ruptured suddenly in the port of Gothenburg while a German tanker **Amalie Essberger** was unloading molten phenol into it in January 1973. The rupture was probably caused by overpressure. 400 tonnes of chemical leaked on the quay and into the water. A large gas cloud formed above the quay. Much of the phenol, especially in the water, soon solidified in the cool weather. Thus the recovery of the phenol was quite easy and no one got injured. However, the measurements made in the water later on showed indications of phenol. Divers searched the area and found large stacks of solidified phenol on the bottom of the sea. These stacks were easily recovered by simple dredging equipment. Control measurement taken afterwards showed no signs of biological damage to the marine fauna (HELCOM 2003: annex 3). Phenol is toxic to both human and aquatic life. However, the bioaccumulation of it is evaluated to be unlikely HSDB 2009).

The efficiency of recovery action in the Amelie Essberger case was partly due to valuable information from a recent phenol accident in Denmark (HELCOM 2003: annex 3). In Denmark some phenol leaked from a tank truck in 1972. Twenty persons were injured, 60 tonnes of sea trout died, and some soil and water got contaminated in the accident. Most of the injured persons were part of the rescue team that were not using adequate protective equipment at the beginning of the rescue operation (Socialstyrelsen 2000). The Gothenburg case showed how important it is to learn from others mistakes. Even if the surroundings of the two cases were different, the most valuable lessons were still adjustable to the later one.

5 CONCLUSIONS

The maritime transport of chemicals has not been studied as excessively as transport of oil in the Baltic Sea region. There are only a limited number of comprehensive studies that cover the whole Baltic Sea. Some studies are very general in nature and some studies are concentrated on more detailed issues or limited areas. The best publications reviewed in this study are already getting outdated.

Data about the maritime transport of chemicals is gathered by many organisations. However, not all the data are comparable with each other, as different classification systems are often used. Some of these systems are more detailed than others. European wide statistics are provided by Eurostat service of the European Union, but these statistics are very general in nature and do not specify chemical transportations. The Finnish PortNet information system collects transport data from all the ships arriving to or departing from a Finnish port. Thus the data is very detailed in nature. To get a comprehensive outlook to the transport rates of the whole Baltic Sea region, a PortNet-like information system should be implemented to all the countries surrounding the sea. At the present usability of the system is somewhat poor for researching purposes, as the data processing is quite time-consuming and laborious.

These observations agree with the statement of EMSA (2007: 20): “In general, the researching of the subject is seen as very difficult due to insufficient data”. To research maritime transport of chemicals comprehensively data gathered from public registers is not enough. Data must be gathered also directly from the port authorities and operators. This can be done for example by questionnaires. However, comprehensive data acquisition may be time-consuming (Hänninen & Rytkönen 2006: 3). In addition, according to experiences of Hänninen and Rytkönen (2006: 3) some ports may be unwilling to share their statistics.

The data about the marine transport of chemicals gets outdated relatively fast. The transportation rates have increased during the last decades and the figures are estimated to grow even further. The growth is not necessarily evenly distributed and thus the relative importance of ports and chemicals may change. New legislations and technical innovations are introduced quite often, which also changes the shipping industry for its part. All these mean that new statistics and data are needed all the time. Actually, it is suggested by HELCOM (1990: 14) that the information needs to be updated and reviewed at intervals of five years. This five-year goal is already missed since the latest comprehensive study is published in 2006 and handles data from year 2004. Thus the main conclusion of this review is that there is a growing need for a new study about the maritime transport of chemicals in the Baltic Sea.

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