

Maritime Transportation, Chemistry and the Environment

Contents

<u>Introduction</u>	2
<u>Ships and maritime transport of goods</u>	3
<u>Risks of tankers</u>	11
<u>Chemicals in tankers</u>	13
<u>Complementary material</u> & <u>further reading</u>	16

Introduction

It is well known that maritime transport has been, is, and will be, a catalyst of economic development and prosperity around the world. It has enabled trade and contacts between cultures. Nowadays it is recognized as the way of ensuring the security of supply of energy, food and commodities, and providing the main vehicle for imports and exports between nations. Maritime industries are an important source of employment and income for the world economy, but at the same time, as almost all human activity, is a potential source of environmental pollution.

According to the information provided by the European Commission¹ shipping is of strategic importance to the EU economy as every year 2 billion tonnes of goods are loaded and unloaded in EU ports, and 1 billion tonnes of oil are transiting through EU ports and EU waters. These numbers will increase in the coming years, which imply higher risks of accidental spills at sea.

Recently, the European Commission has updated its legislation on maritime safety,² and to promote high-quality standards with the aim³ to “eliminate substandard shipping, increase the protection of crews and passengers, **reduce the risk of environmental pollution**, and ensure that operators who follow good practices are not put at commercial disadvantage by others who are prepared to take short cuts with vessel safety”. For details follow the links above.

International agreement resulted in actions in the field of maritime safety and protection of the environment. The International Maritime Organization (IMO)⁴ has the responsibility to develop and maintain a comprehensive regulatory framework for shipping, and its remit today includes safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. As specialized agency of the United Nations with 169 Member States and three Associate Members, IMO is based in the United Kingdom with around 300 international staff. The transposition of IMO rules into the

¹ http://ec.europa.eu/transport/index_en.htm

² http://ec.europa.eu/transport/maritime/safety/third_maritime_safety_package_en.htm

³ http://ec.europa.eu/transport/strategies/2018_maritime_transport_strategy_en.htm

⁴ <http://www.imo.org/>

Member States and Associate Members legal system ensures their enforcement across the entire world.

Ships and maritime transport of goods

Some terms related to ships should be cited:

❖ *Basic terms related to ships and maritime transport* (see figures 1 to 5):

- Aft: the rear part of a ship.
- Amidships: the middle part of a ship (between the front and back).
- Athwart: across, from side to side, transverse, across the line of a vessel's course.
- Ballast tank: one of several tanks in the hold of a ship which may be pumped full of water as ballast.
- Ballast water: water loaded in ships to increase its stability.
- Beam (Breadth): how wide a ship is (from the left to right -facing the bow-).
- Berth: a bed in a cabin, also, a dock for the ship.
- Bilge: the lowest compartment on a ship where the two sides meet. Also, it is used to refer to a mixture of substances, mainly fresh & sea water and oily residues, collected in this compartment.
- Bilge tank: tank used to contain bilge.
- Bow: the front most part of the hull.
- Bridge: the command area where the captain steers the ship.
- Bulbous bow: a protrusion below the waterline forward.
- Cofferdam: an empty space or a ballast space used in ships to give protection from heat, fire, collision, and also to isolate mutually reactive cargoes being carried.
- Deck: a horizontal platform in a vessel that corresponds to a floor in a building.
- Depth: the vertical distance from the bottom of the hull to the uppermost edge at the side (depth = freeboard + draft).
- Draft (Draught): how much of the ship is under water.

- Engine room (ER): machinery spaces of a vessel.
- Freeboard: the difference between depth and draft.
- Funnel or smokestack: the chimney.
- Hatch: a cover used to close and seal a hatchway.
- Hatchway: an opening in the deck through which cargo is transferred or persons enter and exit.
- Hull: the body of a vessel, it provides the buoyancy that keeps the ship from sinking.
- Keel: the main structural member of a ship, running lengthwise along the centre line from bow to stern.
- Knot: unit of speed. 1 knot=1 nautical mile per hour=1.852 km/h=1.151 mph.
- Length: how large the ship is (distance between the bow and the stern).⁵ As shown in Figure 5, there are several lengths, the maximum known as Length Over All (L.O.A).
- Oil barrel (bbl): unit of volume in the oil market. 1 bbl = 42 US gallons = 158.9873 L,
- Port (portside): the left side of the boat when facing the bow.
- Propeller: a type of fan which causes the movement of the ship.
- Prow: the very front of the ship.
- Pump: device used to displace volumes of gases, liquids and slurries.
- Rudder: the means of giving direction to a ship under way.
- Slop: floating oil and solids of the bilge.
- Slop tank: tank used in a vessel to retain the slop generated by tank washings oil residues and dirty ballast residues.
- Starboard: the right side of the boat when facing the bow.
- Steering wheel (or Helm): device used to change the direction of the vessel.
- Stern: rear-most part of the ship.
- Waterline: one of the horizontal lines on the hull of a ship indicating the surface of the water when the ship is under various loads. Also the line of intersection of the surface of the water with the hull of the vessel (LWL).

⁵ Complementary length measurements, like length between perpendiculars (LBP or LPP) are used in describing ship size; the same applies for breadth (molded breadth = registered breadth), draft (molded draft) and depth (molded depth).

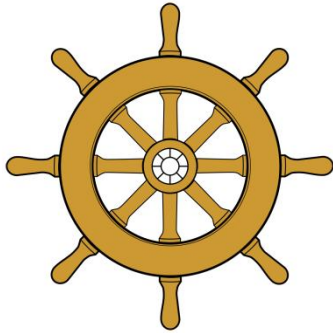


Figure 1. *Steering wheel*⁶

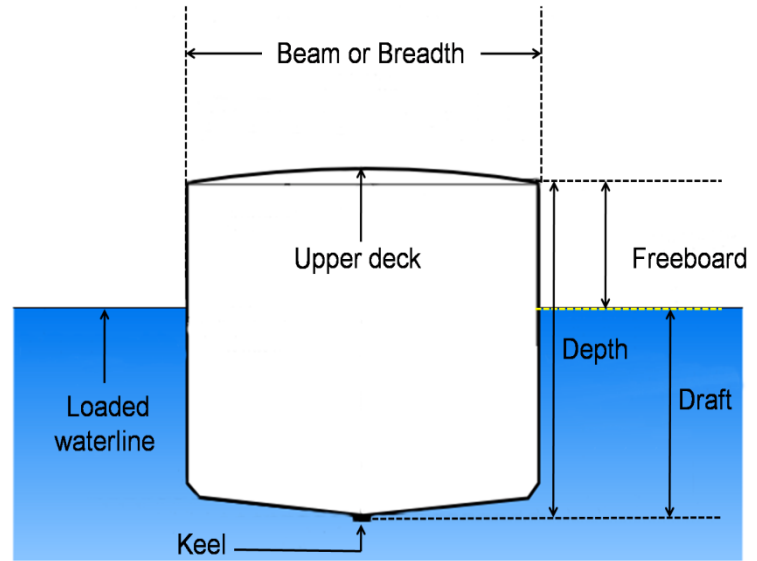


Figure 2. *Ship terms (front view)*⁷

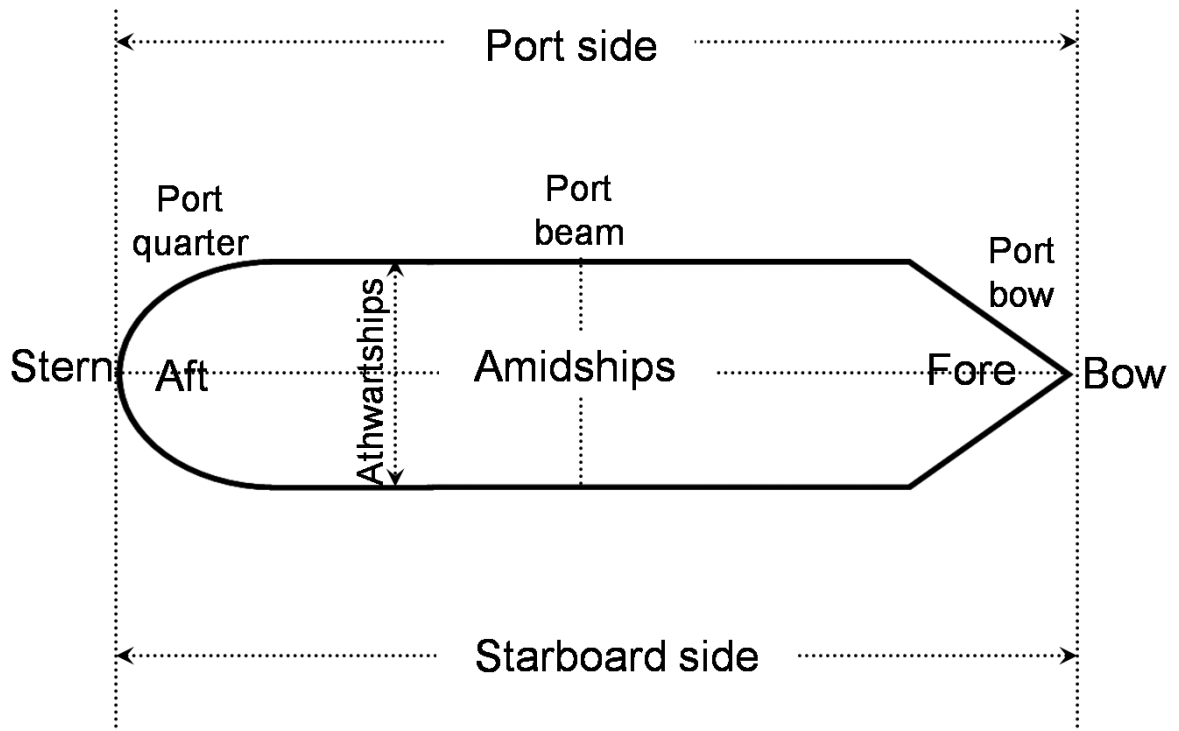


Figure 3. *Ship terms (top view)*

⁶ Taken from http://commons.wikimedia.org/wiki/File:Steering_wheel_ship_1.png

⁷ Adapted from [http://commons.wikimedia.org/wiki/File:Ship_size_\(front_view\).PNG](http://commons.wikimedia.org/wiki/File:Ship_size_(front_view).PNG)

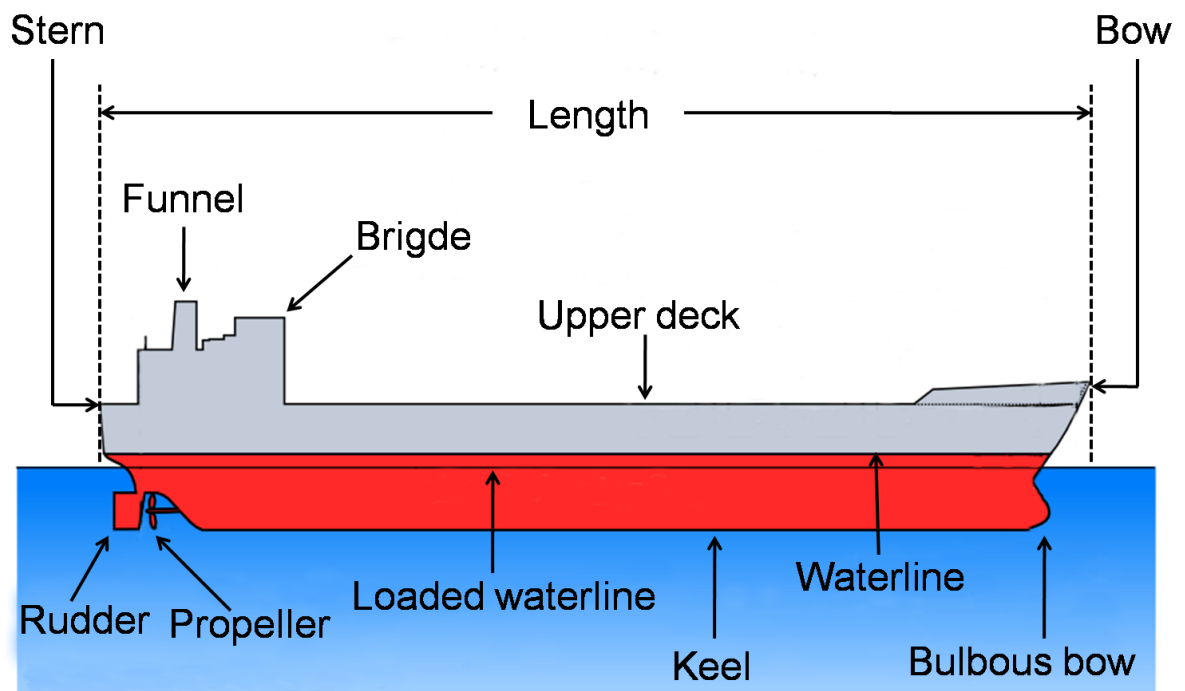


Figure 4. *Ship terms (side view)*⁸

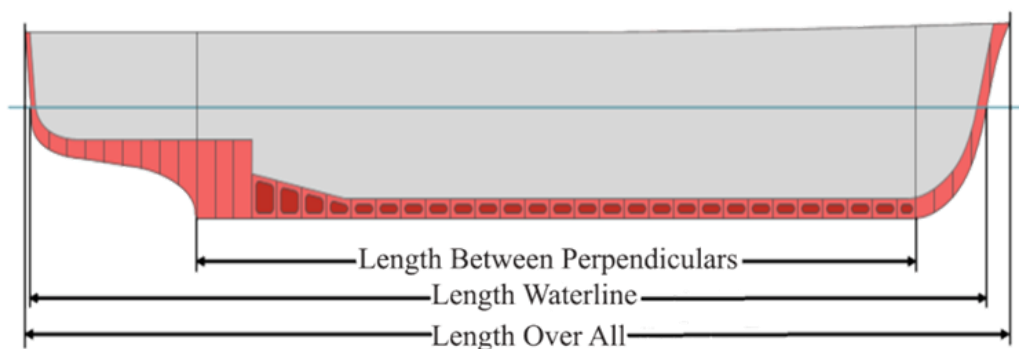


Figure 5. *Length measurement in ships (side view)*⁹

⁸ Adapted from [http://commons.wikimedia.org/wiki/File:Ship_size_\(side_view\).PNG](http://commons.wikimedia.org/wiki/File:Ship_size_(side_view).PNG)

⁹ Adapted from http://en.wikipedia.org/wiki/File:Ship_length_measurements.png

❖ *Related terms to classify vessels: Tonnage and weight* (some standardization has been achieved, but there are still in use different units to express those quantities).

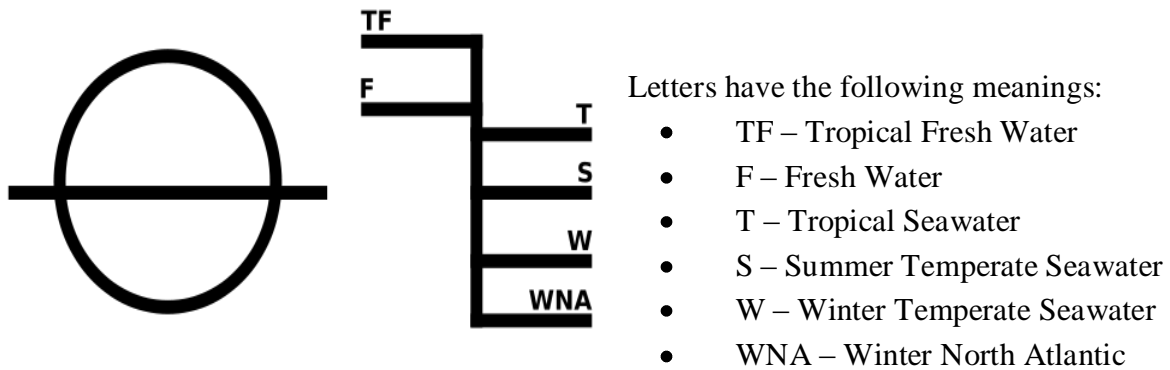
- **Tonnage** (measures the cargo carrying capacity of a ship, and is a universal, and straight-forward, method of calculating ships dues).
 - *Gross Register Tonnage* (GRT): represents the total internal volume of the whole vessel, including crew spaces, bridge, engine compartment, etc.
 - *Net Tonnage* (NT, formerly Net Register Tonnage –NRT–): the volume of cargo the ship can carry, i.e., available volume for transporting freight or passengers.
 - *Gross Tonnage* (GT) is a function of the volume of a ship's enclosed spaces, i.e., the ship's overall internal volume. Both GT and NT are estimated by measuring ship's volume and then applying a mathematical formula. Further reading on Tonnage Measurement of Ships.¹⁰
- **Weight**
 - *Displacement*: the actual total weight of the vessel, usually expressed in metric tons (m.t.).¹¹ It is easily estimated by multiplying the volume, in m³, of the hull below the waterline by the density of the water, in kg/m³. Notice that the density of water varies with temperature and the content of salts, i.e., it is not the same for fresh or sea water. Usually 1.025 is used for the specific gravity of sea water.
 - *Lightship* (or Lightweight): the actual weight of the vessel with nothing on board (crew, fuel, cargo, water, etc.).
 - *Deadweight tonnage* (DWT): the displacement at any loaded condition minus the lightship weight. DWT serves to classify vessels by weight.

Specific water types and temperatures determine the legal limit to which a ship may be loaded, which is indicated on the hull by the Load Line (or Plimsoll Line)¹² positioned amidships. Plimsoll lines are shown below:

¹⁰ Taken from http://www.imo.org/Conventions/contents.asp?topic_id=259&doc_id=685

¹¹ Metric ton: is a unit of mass equal to 1,000 kg (or 2,204.62262 lb).

¹² As curiosity, the former Plimsoll line (a circle with a horizontal line through it) it is the same symbol used to design standard state in chemistry.



Plimsoll line¹³



Taken from Wikimedia¹⁴



Taken from Wikimedia¹⁵

Figure 6. *Images of the Plimsoll line*

Letters appearing to the sides of the line crossing the circle state the classification society that has surveyed the ship's load line. Classification societies,¹⁶ Class societies for short, are responsible for supervising, in construction and in service, the compliance of the corresponding international standards. The oldest Class society, founded in 1760, is the Lloyd's Register of Shipping (LR).

Ships allow transport of any kind of goods in large amounts, but not all vessels are able to carry everything. In this context a simple classification regarding maritime transportation of goods can be done:

- General cargo

¹³Taken from http://commons.wikimedia.org/wiki/File:Brosen_plimsoll_line_en.svg

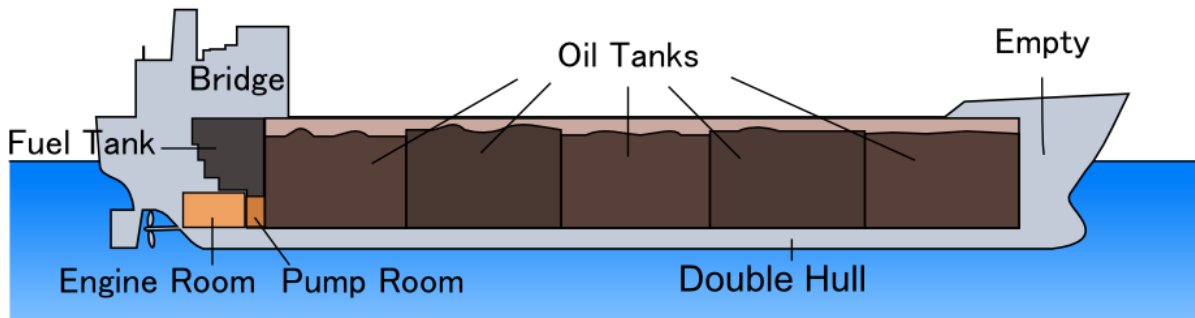
¹⁴ Taken from http://commons.wikimedia.org/wiki/File:Brosen_plimsoll_line1.jpg

¹⁵ Taken from [http://commons.wikimedia.org/wiki/File:Germanischer_Lloyd_03_\(RaBoe\).jpg](http://commons.wikimedia.org/wiki/File:Germanischer_Lloyd_03_(RaBoe).jpg)

¹⁶ See http://en.wikipedia.org/wiki/Classification_society.

- Container ships
- Bulk carriers or bulkers (e.g. RORO)¹⁷
- **Tankers** (e.g. oil tankers –see Fig. 7–)

Oil tanker (side view)



Oil tanker (front view) Center cut view

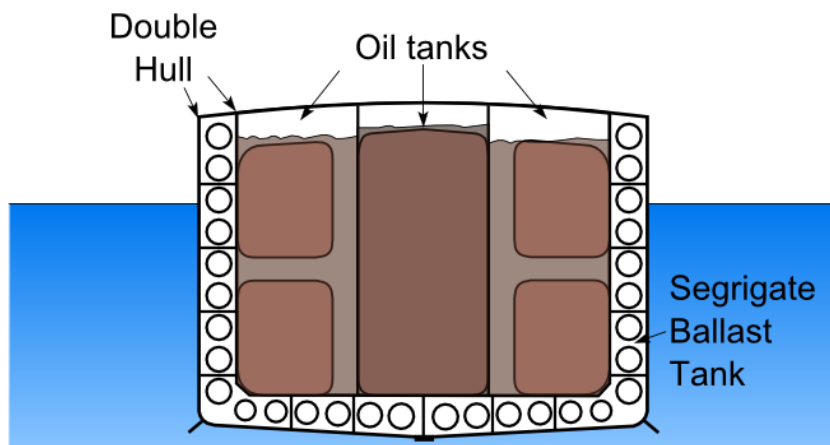


Figure 7. Side and front view of a double hull Oil Tanker^{18,19}

¹⁷ RORO (also Roll-on/roll-off or ro-ro) vessels carry wheeled cargo (automobiles, trailers, etc.) that are driven on and off the ship on their own wheels. On the other hand, lo-lo (lift on-lift off) ships use a crane to load and unload cargo.

¹⁸ Taken from [http://commons.wikimedia.org/wiki/File:Oil_tanker_\(side_view\).PNG](http://commons.wikimedia.org/wiki/File:Oil_tanker_(side_view).PNG)

¹⁹ Taken from [http://commons.wikimedia.org/wiki/File:Oil_tanker_\(front_view\).PNG](http://commons.wikimedia.org/wiki/File:Oil_tanker_(front_view).PNG)

A tanker (tank ship or tankship) is a ship designed to transport liquids in bulk. Major types of tank ship include:

- *Chemical tankers*: vessels designed to transport chemicals in bulk. Their size is considerably smaller than the average size of other tanker types due to the specialized natures of their cargoes.
- *LPG and LNG tankers*: ships transporting liquefied petroleum gas (LPG), and liquefied natural gas (LNG).
- *Oil tankers* (also petroleum tankers): ships designed for the bulk transport of oil. There are two main types: crude tankers (unrefined oil), and product tankers (refined products). The crude oil tankers are distinguished according to their size, usually measured in dwt (see Table 1). Sometimes transportation of liquid and dry cargo is alternate, in such case those ships are known as OBO (Ore / Bulk / Oil). PROBO (or combination carrier) is used for (product / ore / bulk / oil) carrier.

Table 1. *Size of oil tankers (gross figures)*

Type	Length / m	Beam / m	Draft / m	Typical dwt range / m.t.
Seawaymax ^a	225	32	8	10,000-60,000
Panamax ^b	290	32	12	60,000-80,000
Aframax ^c	245	34	20	80,000-120,000
Suezmax ^d	285	45	23	120,000-200,000
VLCC ^e	350	55	28	200,000-320,000
ULCC ^f	415	63	35	320,000-550,000

^a Largest vessels fit through the canal locks of the St. Lawrence Seaway.; ^b Largest ships able to pass through Panama Canal.; ^c Term coming from the Average Freight Rate Assessment (AFRA) tanker rate system; ^d Largest vessels capable of transiting the Suez Canal fully loaded.; ^e Very Large Crude Carrier (for example largest ships capable of fitting through the Strait of Malacca –Malaccamax-).; ^f Ultra Large Crude Carrier.

Previous classification is the so called the flexible market scale, which is a bit different from the AFRA (average freight rate assessment) scale: General Purpose tanker, Medium Range tanker, LR1 -Large Range 1-, LR2 -Large Range 2-, VLCC, and ULCC.

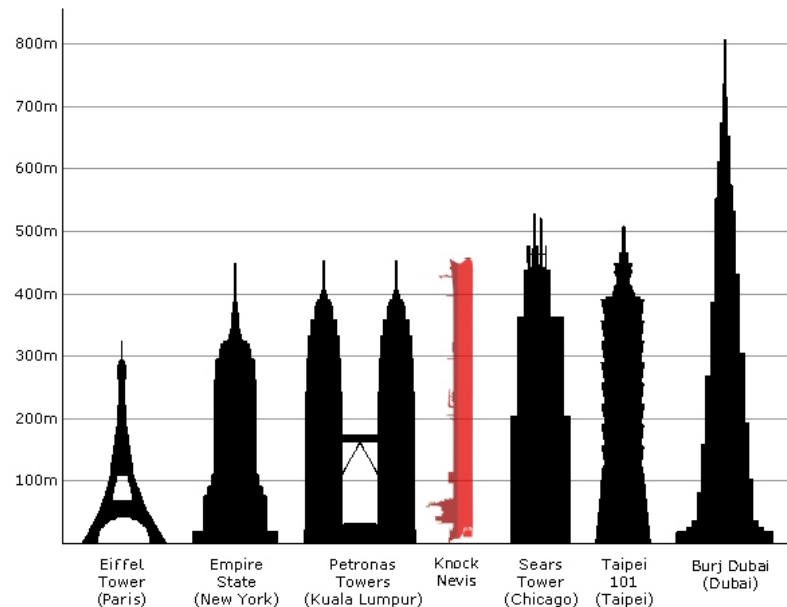


Figure 8. *Relative size of the largest ULCC and famous buildings*²⁰

Largest tankers are oil tankers, which are able to carry out huge amounts of oil, according to their high deadweight tonnage (dwt) their length is. Figure 8 compares the size of the largest ever built vessel with the world's tallest buildings. As a rule of thumb the volume carried in a tanker is a function of the cube of its length. Although at first sight this could be an advantage, at least from the economical point of view, problems come from the lack of ports with appropriate capacity and its reduced maneuverability, for example, the turning diameter a loaded supertanker is about 2 kilometers, and it takes at least 15 minutes to come to a full stop, which implies about 3 kilometers.

Risks of tankers

In addition to risks associated to passenger or fishing ships, tankers also pose extra risks to crew, ship itself and environment due to the nature of goods being transported.

²⁰ Taken from <http://commons.wikimedia.org/wiki/File:Tanker-size-comparison.png>

Current tanker operation implies both air and sea water pollution (e.g. exhaust gas, and ballast water respectively), which could also involve shoreline and ocean floor pollution (e.g. black tides) in case of accident, usually having heavy effects, short, middle and long term, on the environment (see Figure 8).

POLLUTION BY CHEMICAL AND OIL TANKERS

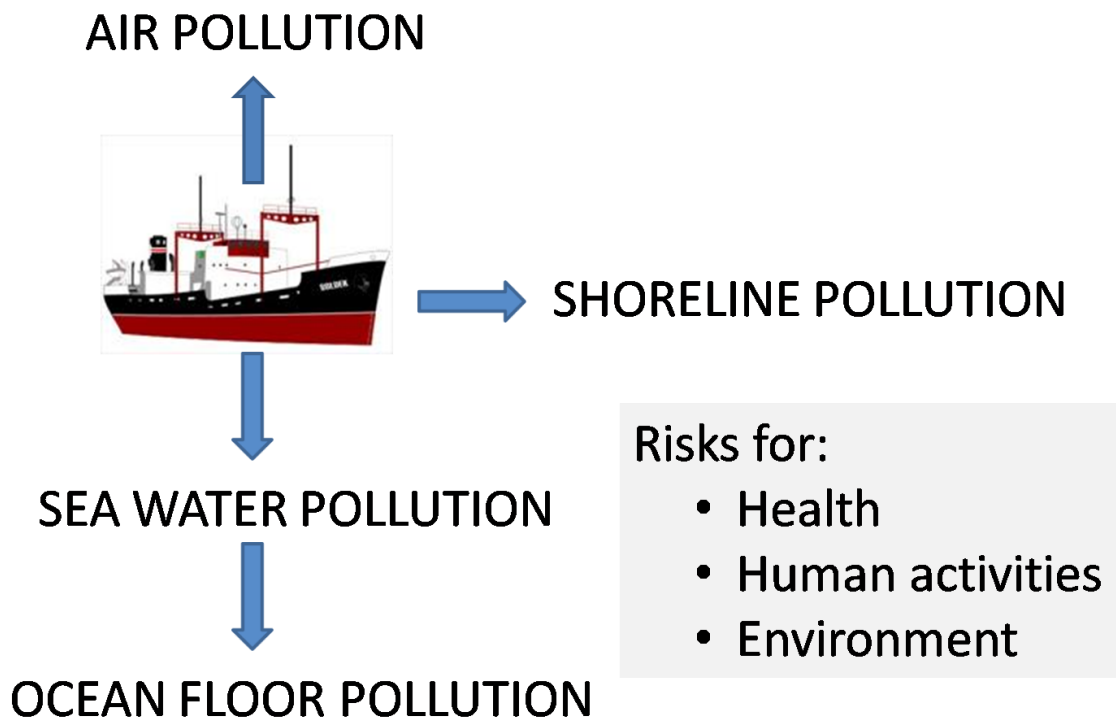


Figure 8. *Pollution from chemical and oil tankers and associated risks*

Big accidents in the 1960's, e.g. Torrey Canon, forced international regulation of the maritime transportation of goods, as a result many operating codes must be taken into account, the major ones being (each code accounting at least one aspect of maritime transport):

- **ISM/ISO:** Operating Documentation and Compliance
- **STCW:** Crew Qualifications
- **MARPOL:** Pollution Prevention
- **IMDG:** International Maritime Dangerous Goods Code

- **SOLAS:** Safety and Life Saving
- **ISPS:** Ship and Port Security

Regulation of worldwide maritime transportation is a difficult task, as there is a complex responsibility chain (see Figure 9 –Courtesy of INTERTANKO²¹–).

Tanker industry

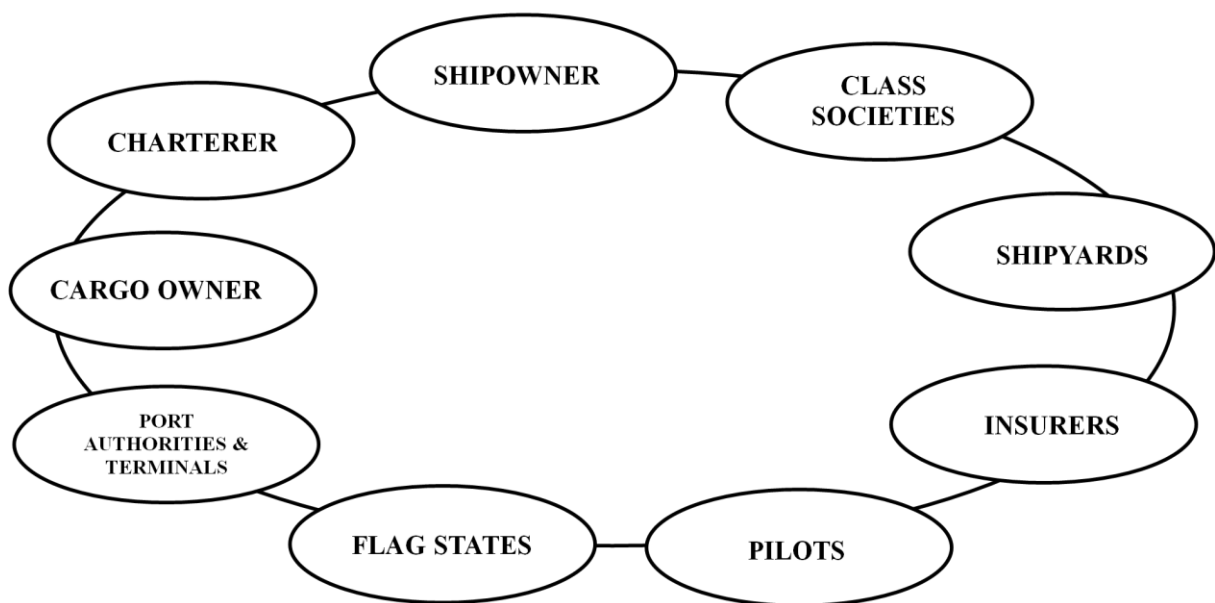


Figure 9. Chain responsibility in the tanker industry

Chemicals in tankers

Tankers carry a broad range of products which usually pose a number risks in the case of accident. As stated before, products in bulk are transported either by chemical carriers (liquid substances at room temperature), or by gas carriers (gaseous substances). The capacity of tankers for chemical products varies from 400m³ to 40.000 m³ -gas carriers up to 100.000 m³-, each tank ranging from 70 m³ to 2.000 m³.

²¹ Taken from <http://www.intertanko.com/>

The International Maritime Organization establishes the construction norms of ships carrying chemical products:

- chemical products in bulk (liquid): the IBC code²²;
- liquefied gases in bulk: the IGC code²³;
- solids in bulk: the BC code²⁴.
- construction and equipment of ships carrying dangerous chemicals in bulk: the BCH Code²⁵.

Considering chemicals in a broad sense, there are two main classes of chemicals on board:

- Operating (substances used in the routine operation of the vessel), these include:
 - Fuels
 - Lubricants
 - Gases (inertization, refrigeration, ...)
 - Fire-fighting compounds
 - Paints
 - Tank cleaning chemicals
 - Antifouling products
 - Products for water treatment (e.g. for boiler water conditioning)
- Transported: most common chemical products transported in bulk can be simply classified as:
 - ♦ heavy chemical products produced in large quantities (e.g. ammonia, caustic soda, or acids like sulphuric, chlorhydric, etc.),
 - ♦ alcohols & molasses (by-products of sugar cane or sugar beets processing into sugar);

²² See http://www.imo.org/Environment/mainframe.asp?topic_id=1174

²³ See http://www.imo.org/environment/mainframe.asp?topic_id=995

²⁴ See http://www.imo.org/Newsroom/mainframe.asp?topic_id=113&doc_id=2800

²⁵ See http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258

- ♦ vegetable oils (e.g. corn, oil, soya, sunflower, etc.) and animal oils (e.g. fish oils) ;
- ♦ petrochemical products (e.g. vinyl chloride, benzene, xylene, phenol, styrene, etc.);
- ♦ coal tar products (e.g. benzene, naphthalene, etc.)

Complementary material & further reading

Complementary material:

- PowerPoint file: *ships_terms_oer.ppsx*
- Self evaluation tests: *mar_trans_chem_en_test_oer (WinRAR Zip)*

Further reading

Introduction to Marine Cargo Management (Lloyd's Practical Shipping Guides) by J. Mark Rowbotham. Publisher: Informa Law (June 2008).

Ship Construction (Sixth Edition) by D. J. Eyres. Publisher: Butterworth-Heinemann (April 2007).

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