The Management of Ship-Generated Waste On-board Ships

EMSA/OP/02/2016

CHEW

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Content

Summary

This study provides an empirical overview of the management, drivers, technologies and the quantities of different categories of ship-generated waste. The data presented in this report have been collected from ship audits, interviews, a literature review, an online survey among stakeholders and audits of waste notification forms.

For almost every type of ship-generated waste, there is a variety of waste flows and on-board treatment methods. The empirical evidence gathered in this study shows that ships use different treatment methods and often only treat part of a waste stream. This results in a difference between the amounts of waste generated and the amounts landed.

Table 1 presents a summary of the results of the empirical analysis.

Table 1 Overview of the amounts of waste generated, drivers and treatment methods

Type of waste	Generation rate	Driver	On-board treatment
Oily bilge water	0.01-13 m^3 per day, larger ships generate larger quantities.	Condensation and leakages in the engine room; size of the ship.	The amount can be reduced by 65-85% by using an oil water separator and discharging the water fraction into the sea.
Oily residues (sludge)	0.01 to 0.03 m^3 of sludge per tonne of HFO. 0 and 0.01 m^3 per tonne of MGO.	Type of fuel; fuel consumption.	Evaporation can reduce the amount of sludge by up to 75%. Incineration can reduce the amount of sludge by 99% or more.
Tank washings (slops)	20 to hundreds of m^3	Number of tank cleanings; Size of loading capacity.	After settling, the water fraction may be discharged at sea.
Sewage	0.01 to 0.06 m^3 per person per day. Sewage is sometimes mixed with other waste water. The total amount ranges from 0.04 to 0.45 m^3 per day per person.	Number of persons on-board; type of toilets; length of voyage.	Effluent from treatment plants is often discharged at sea where permitted under MARPOL Annex V.
Plastics	0.001 to 0.008 m^3 of plastics per person per day.	Number of person on-board.	Often not incinerated. Dirty plastics (plastics that have been in contact with food) are often treated as a separate waste stream.
Food wastes	0.001 to 0.003 m^3 per person per day.	Number of persons on-board; provisions.	Where permitted under MARPOL Annex V, food waste is often discharged at sea.
Domestic wastes	0.001 to 0.02 m^3 per day per person.	Number of persons on-board; type of products used.	

Type of waste	Generation rate	Driver	On-board treatment
Cooking oil	0.01 to 0.08 litres per person per day.	Number of persons on-board; type of food prepared.	Although not permitted, cooking oil is sometimes still added to the sludge tank.
Incinerator ashes	0.004 and 0.06 m^3 per month.	Use of incinerator; cost of using incinerator.	The incinerator is not used for all types of waste, mostly for paper sometimes for oily sludge.
Operational wastes	0.001 to 0.1 m^3 per person per day.	Size of the ship; type of cargo.	
Cargo residues	0.001-2 % of cargo load.	Type of cargo. Size of ship.	

List of abbreviations

AWTS - Advanced Wastewater Treatment System

COW – Crude Oil Washing

EEDI - Energy Efficiency Design Index

EMSA – European Maritime Safety Agency

ESSF – European Sustainable Shipping Forum

GRB – Garbage Record Book

HCFC – Hydro chlorofluorocarbons

HFO – Heavy Fuel Oil

IOPP – International Oil Pollution Prevention

IMO – International Maritime Organisation

ISPP – International Sewage Pollution Prevention

MARPOL - International Convention for the Prevention of Pollution from Ships

MEPC - Marine Environment Protection Committee

MGO - Marine Gas Oil

MSD - Marine Sewage Device

ODMCS – Oil Discharge Monitoring and Control System

ODM-E – Oil Discharge Monitoring Equipment

ORB – Oil Record Book

OWS – Oil Water Separator

PCB – polychlorinated biphenyls

Ppm – parts per million

PVC – polyvinyl chlorides

PRF – Port Reception Facility

RO - Reverse Osmosis

SGW – Ship Generated Waste

1 Introduction

1.1 Background, objective and methods

EMSA is assisting the European Commission in its work on the potential revision of Directive 2000/59/EC (EC, 2000) on port reception facilities for ship-generated waste and cargo residues, also called the PRF Directive. One of the issues that have been raised is the quantity of ship-generated waste (SGW) on-board of ships and how it is managed. The literature on this issue is outdated and does not reflect new developments in waste handling and treatment. Better information on the amount of waste generated during a voyage, the waste management practices on-board of ships and on the amount of waste discharged in ports, would help regulators, ports and waste handlers plan for the reception and delivery of waste.

The objectives of this study are:
1. To provide a detailed review of the waste practices and management of ship-generated waste on-board on the range of ships visiting EU ports.
2. To provide average quantities of different types of waste being generated on-board of ships.
3. To provide a comprehensive review of the present technologies and methods being used to reduce SGW produced by ships.

The study has an empirical nature; the findings are based on:
- interviews with shipping companies, ports, waste handlers and technology providers;
- audits of garbage management plans, International Oil Pollution Prevention (IOPP) certificates, International Sewage Pollution Prevention (ISPP) certificates, garbage management books, oil record books (ORB) and ozone depleting substances (ODS) record books of ships;
- audits of waste notification forms and delivery receipts;
- a literature review; and
- an internet survey to validate the results.

The empirical basis of the study was gathered in 13 ship audits, 25 interviews (see Annex B for an overview) and from 33 participants in the internet survey. The aim of the audits and interviews was to obtain copies of oil record books and garbage record books (GRB), and gather information on waste generation, treatment and handling on-board. While it was possible to obtain these data on all ship audits, it was not possible for every interview because copies of relevant record books are not regularly kept on shore. The information from the record books was analysed to obtain estimates of the quantities of waste generated and delivered to PRF.

The relatively small size of the sample means that the results presented in the following chapters cannot always be extrapolated to the entire fleet. In some cases, like oily residues, the amounts of waste generated in the entire sample lies within a small range which is consistent with information found in the literature. Consequently, we are confident that this range is valid for most ships. In other cases, however, there is a large variation between ships that cannot be ascribed to ship types or other characteristics. In these cases, the ranges presented in this report can serve as an indication of the quantities of waste, but should not be considered to be statistical averages.

1.2 Scope of the study

The ship types that were included in this study were: cruise ships, oil tankers, gas carriers, bulk carriers, container vessels, ro-ro cargo vessels, ferries, recreational craft and fishing vessels.

All types of ship-generated waste as defined in Marine Environmental Protection Committee (MEPC) 1.Circ 834 (IMO, 2014) will be included in the study, with the exception of waste from Exhaust Gas Cleaning Systems.[1] More specifically, the following types of waste will be included (see Table 2):
- oily waste;
- sewage;
- garbage;
- ozone depleting substances.

Table 2 Types of waste

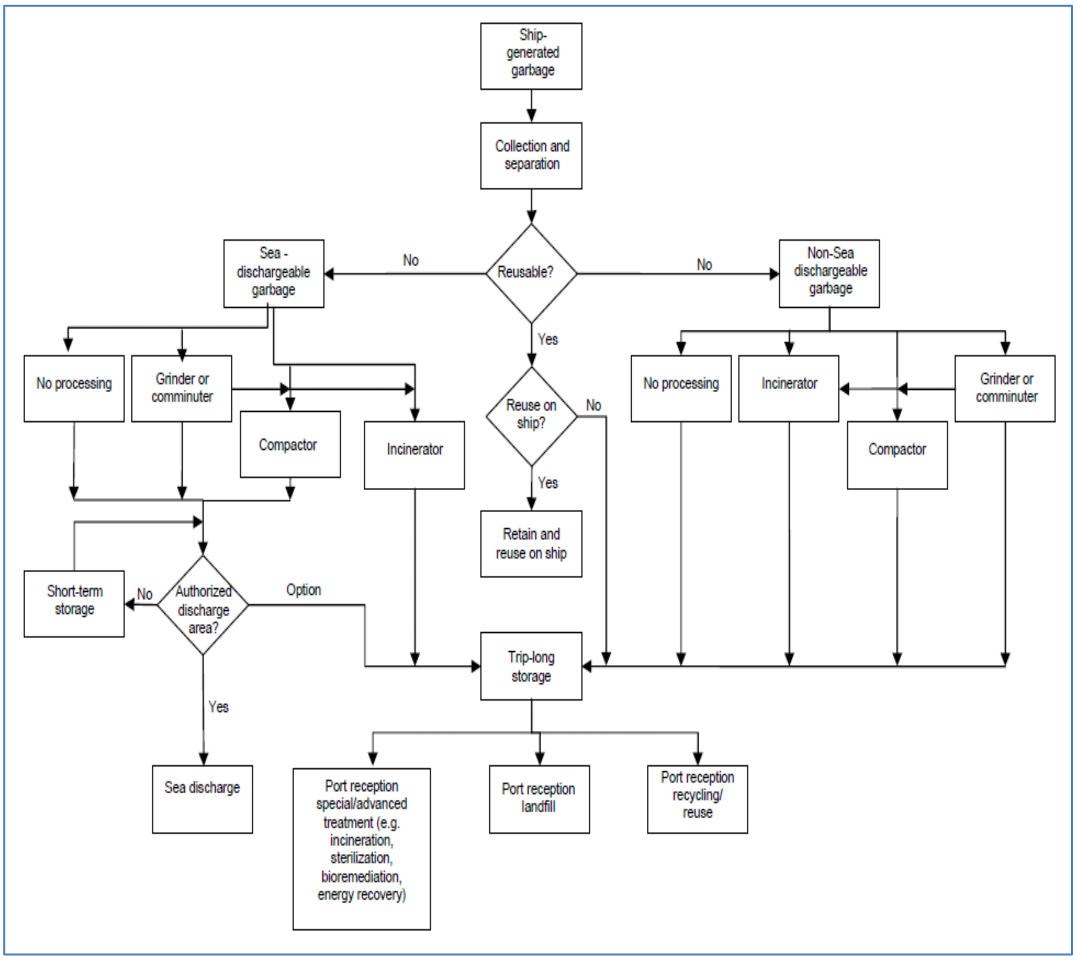
MARPOL Annex V-related	MARPOL Annex I-related	MARPOL Annex IV-related	MARPOL Annex VI-related
A. Plastics	Oily bilge water	Sewage	Ozone depleting substances
B. Food wastes	Oily residues (sludge)		
C. Domestic wastes	Oily tank washings (slops)		
D. Cooking oil	Dirty ballast water		
E. Incinerator ashes	Scale and sludge from tank cleaning		
F. Operational wastes			
G. Cargo residues			
H. Animal carcass(es)			
I. Fishing gear			

Source: (IMO, 2014).

There are several options to manage ship-generated waste. An overview of these options from the 2012 guidelines for the implementation of MARPOL ANNEX V is presented in Figure 1.

1 Wastes from Exhaust Gas Cleaning Systems (EGCSs) have been significantly discussed in the EGCS subgroup of the European Sustainable Shipping Forum (ESSF). Therefore, this study did not audit ships with an EGCS.

Figure 1 Overview of options for shipboard handling and discharge of garbage



Source: (IMO, 2012a).

1.3 EU legislation

The European Directive 2000/59/EC on port reception facilities (PRF) for ship-generated waste and cargo residues describes the European legislation on the treatment and delivery of SGW in European ports. The European Union aims to develop the availability and use of reception facilities in order to reduce discharges into the sea of SGW. In this Directive, the following is stated regarding PRF and waste handling procedures (EC, 2000):

- *'Member States shall ensure the availability of port reception facilities adequate to meet the needs of the ships'.*
- *'An appropriate waste reception and handling plan shall be developed and implemented for each port'.*
- *'...A ship may proceed to the next port of call without delivering the ship-generated waste, if it follows from the information given in accordance with Article 6 and Annex II, that there is **sufficient dedicated storage capacity** for all ship-generated waste that has been accumulated and will be accumulated during the intended voyage of the ship until the port of delivery.'*

1.4 IMO legislation

The legislation on on-board processing of SGW is described in the IMO MARPOL Convention. MARPOL has six Annexes of which five relate to waste in the scope of this study:

- oily waste (sludge, bilge water, engine oil, Annex I);
- cargo residues (Annex II and V);
- sewage (Annex IV);
- garbage (food waste, plastic, Annex V);
- ozone depleting substances (Annex VI).

1.4.1 MARPOL ANNEX I

Regulation on the prevention of pollution by oil can be found in Annex I of MARPOL. Regulation 15 and 17 provide requirements for machinery spaces of all ships (IMO, 2016); (IMO, 2006a):

- Regulation 15: Discharge of oil or oily mixtures from ships of 400 gross tonnage and above into the sea is generally prohibited. The oil residues which cannot be discharged into the sea in compliance with this regulation should be retained on-board for subsequent discharge to reception facilities. In the case of a ship of less than 400 gross tonnage, oil and all oily mixtures should either be retained on-board for subsequent delivery to reception facilities or discharged into the sea given certain provisions. Only when a number of criteria are met, including that the oil content may not exceed 15 ppm, may water contaminated with oil be discharged in the sea by way of exception to this general rule.
- Regulation 17: Oil tankers of 150 gross tonnage and above and other ships of 400 gross tonnage and above should have an Oil Record Part I book which has to be completed if a machinery space operation takes place. In case of oil discharge a statement has to be made in the Oil Record Book Part I.

Regulation 34 and 36 provide requirements on the handling of waste from oil cargo:

- Regulation 34: Any discharge into the sea of oil or oily mixture from the cargo area of an oil tanker is prohibited while in a special area. In the case of discharges outside a special area, discharge into the sea of oil or oily mixtures from the cargo area of an oil tanker is prohibited except when several conditions are satisfied. The oil residues which cannot be discharged into the sea should be retained on-board for subsequent discharge to reception facilities.
- Regulation 36: Oil tankers of 150 gross tonnage and above should have an Oil Record book Part II which has to be completed if a cargo/ballast operation takes place. In case of oil or oily mixture discharge a statement has to be made in the Oil Record Book Part II.

An exception on Regulation 15 and 34 is the discharge at sea in case of securing the safety of a ship and those on-board and to save a life at sea. It is also allowed to discharge in case of discharge as a result of damage to a ship provided all precautions have been taken.

1.4.2 MARPOL ANNEX II

Although Annex II waste is beyond the scope of the empirical part of this study, a brief discussion on cargo residues is included here in order to present a complete overview of the IMO legislation.

Regulation for the control of pollution of noxious liquid substances in bulk can be found in Annex II. Annex II contains a set of regulations including Regulation 13 on the control of discharge of residues of noxious liquid substances.
The following regulations are relevant for cargo residues (IMO, 2016):

- Ventilation of cargo residues may be used to remove cargo residues from a tank. Water that is introduced in the tank after the ventilation will be regarded as clean.
- An exemption of a prewash can be granted in the case that the cargo residues will be removed by a ventilation procedure.
- The procedures for ventilation of cargo residues are described in Appendix 7 of Annex 7. Cargo residues that are allowed to be removed from a cargo tank by ventilation are substances with a vapour pressure greater than 5kPa at 20°C.
- It is allowed to discharge at sea in case of securing the safety of a ship and those on-board and to save a life at sea. It is also allowed to discharge in case of discharge as a result of damage to a ship provided all precautions have been taken.

Regulation 6 describes the categorisation of noxious liquid substances:

- Category X: Noxious liquid substances which, if discharged into sea are considered to present a major hazard to the marine resources or human health and are prohibited to be discharged into the marine environment;
- Category Y: Noxious liquid substances which, if discharged into sea are considered to present a hazard to the marine resources or human health or cause harm to amenities or other legitimate uses of the sea and are limited on the quality and quantity of discharge into the marine environment;
- Category Z: Noxious liquid substances which, if discharged into sea are considered to present a minor hazard to the marine resources or human health and have less stringent restrictions on the quality and quantity of discharge into the marine environment;
- Other substances: Other substances that are considered not to present harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged and which are not subject to any requirements.

1.4.3 MARPOL ANNEX IV

Regulation for the prevention of pollution by sewage can be found in Annex IV of MARPOL (IMO, 2016). Annex IV contains a set of regulations regarding the discharge of sewage into the sea from ships, including:

- regulations regarding the ships' equipment and systems for the control of sewage discharge;
- the provision of port reception facilities for sewage; and
- requirements for survey and certification.

It is generally considered that on the high seas, the oceans are capable of assimilating and dealing with raw sewage through natural bacterial action. Therefore, the regulations in Annex IV of MARPOL prohibit the discharge of sewage into the sea within a specified distance from the nearest land, unless otherwise provided.

The revised Annex applies to new ships engaged in international voyages of 400 gross tonnage and above or which are certified to carry more than 15 persons and includes the following requirements:

- The Annex requires ships to be equipped with either an approved sewage treatment plant or an approved sewage comminuting and disinfecting system or a sewage holding tank.
- The discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than 3 nautical miles from the nearest land.
- Sewage which is not comminuted or disinfected may be discharged at a distance of more than 12 nautical miles from the nearest land, and the rate of discharge of untreated sewage shall be approved by the Administration (see resolution MEPC.157(55) (MEPC, 2006)).
- It is allowed to discharge at sea in case of securing the safety of a ship and those on-board and to save a life at sea. It is also allowed to discharge in case of discharge as a result of damage to a ship provided all precautions have been taken.

A special area established under Annex IV is the Baltic Sea area. The discharge of sewage from passenger ships within the special area will generally be prohibited under the new regulations, except when the ship has in operation an approved sewage treatment plant which has been certified by the Administration. The sewage treatment plant installed on a passenger ship intending to discharge sewage effluent in special areas should meet more stringent nitrogen and phosphorus removal standards (tertiary treatment[2]). The discharge of sewage from passenger ships within special areas are prohibited after 1 January 2019 for new passenger ships and after 1 January 2021 for existing passenger ships (MEPC, 2016)

1.4.4 MARPOL ANNEX V

Regulation for the prevention of pollution by garbage from ships can be found in Annex V which applies for all types of ships. In July 2011, MEPC 62 adopted the revised MARPOL Annex V which entered into force on the first of January 2013 (MEPC, 2011). Garbage is defined as all kinds of food, domestic and operational waste, all plastics, cargo residues, incinerator ashes, cooking oil, fishing gear, and animal carcasses. Garbage does not include fresh fish (parts) as a result of fishing activities or as a result of aquaculture activities.

Annex V prohibits the discharge of garbage except as provided otherwise in the regulations 4, 5, 6 and 7 of the Annex:

- Regulation 4: Cleaning agents or additives may be discharged into sea, if they are not harmful to the marine environment. The discharge of the following garbage outside special areas shall only be permitted while the ship is en route and as far as practicable from the nearest land, but not less than:
  - 3 nm from the nearest land for food wastes which have been passed through a comminuter or grinder with a screen less than 25mm.
  - 12 nm from the nearest land for food wastes that have not been treated in accordance with previous paragraph.

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[2] Tertiary treatment is the removal of for example nutrients, secondary treatment is the removal of organic matter and primary treatment is the removal of solids. (World Bank Group, 2016)

        - 12 nm from the nearest land for cargo residues that cannot be recovered using commonly available methods for unloading. These cargo residues shall not contain any substances classified as harmful to the marine environment, taking into account guidelines developed by the Organization.
        - For animal carcasses, discharge shall occur as far from the nearest land as possible, taking into account the guidelines developed by the Organization
- Regulation 5: The discharge into the sea of any garbage is prohibited from fixed or floating platforms and from all other ships when alongside or within 500 m of such platforms. Food wastes may be discharged into the sea from fixed or floating platforms located more than 12 nautical miles from the nearest land and from all other ships when alongside or within 500 m of such platforms, but only when the wastes have been passed through a comminuter or grinder. Such comminuted or ground food wastes shall be capable of passing through a screen with openings no greater than 25 mm.
- Regulation 6: Discharge of the following garbage into the sea within special areas shall only be permitted while the ship is en route and as follows:
    - Discharge into the sea of food wastes as far as practicable from the nearest land, but not less than 12 nautical miles from the nearest land or the nearest ice shelf. Food wastes shall be comminuted or ground and shall be capable of passing through a screen with openings no greater than 25 mm. Food wastes shall not be contaminated by any other garbage type. Discharge of introduced avian products, including poultry and poultry parts, is not permitted in the Antarctic area unless it has been treated to be made sterile.
    - Discharge of cargo residues that cannot be recovered using commonly available methods for unloading, where all the following conditions are satisfied:
        - Cargo residues, cleaning agents or additives, contained in hold washing water do not include any substances classified as harmful to the marine environment, taking into account guidelines developed by the Organization;
        - Both the port of departure and the next port of destination are within the special area and the ship will not transit outside the special area between those ports;
        - No adequate reception facilities are available at those ports taking into account guidelines developed by the Organization; and
        - Where the conditions of subparagraphs 2.1, 2.2 and 2.3 of this paragraph have been fulfilled, discharge of cargo hold washing water containing residues shall be made as far as practicable from the nearest land or the nearest ice shelf and not less than 12 nautical miles from the nearest land or the nearest ice shelf.
- Cleaning agents or additives contained in deck and external surfaces wash water may be discharged into the sea, but only if these substances are not harmful to the marine environment, taking into account guidelines developed by the Organization.

- The following rules (in addition to the rules in paragraph 1 of this regulation) apply with respect to the Antarctic area:
  - Each Party at whose ports ships depart en route to or arrive from the Antarctic area undertakes to ensure that as soon as practicable adequate facilities are provided for the reception of all garbage from all ships, without causing undue delay, and according to the needs of the ships using them.
  - Each Party shall ensure that all ships entitled to fly its flag, before entering the Antarctic area, have sufficient capacity on board for the retention of all garbage, while operating in the area and have concluded arrangements to discharge such garbage at a reception facility after leaving the area.
  - When garbage is mixed with or contaminated by other substances prohibited from discharge or having different discharge requirements, the more stringent requirements shall apply.
- Regulation 7: Exceptions of regulation 3,4,5 and 6 are:
  - The discharge of garbage from a ship necessary for the purpose of securing the safety of a ship and those on board or saving life at sea; or
  - The accidental loss of garbage resulting from damage to a ship or its equipment, provided that all reasonable precautions have been taken before and after the occurrence of the damage, to prevent or minimize the accidental loss; or
  - The accidental loss of fishing gear from a ship provided that all reasonable precautions have been taken to prevent such loss; or
  - The discharge of fishing gear from a ship for the protection of the marine environment or for the safety of that ship or its crew.
  - The en route requirements of regulations 4 and 6 shall not apply to the discharge of food wastes where it is clear the retention on board of these food wastes presents an imminent health risk to the people on board

- ANNEX V provides several regulations on control and enforcement of the disposal prohibition of garbage: Regulation 8: Each Party undertakes to ensure the provision of adequate facilities at ports and terminals for the reception of garbage without causing undue delay to ships, and according to the needs of the ships using them.
- Regulation 9 : A ship when in a port or an offshore terminal of another Party is subject to inspection by officers duly authorized by such Party concerning operational requirements under this Annex, where there are clear grounds for believing that the master or crew are not familiar with essential shipboard procedures relating to the prevention of pollution by garbage. Procedures relating to the port State control as prescribed in article 5 also apply to this regulation
- Regulation 10: Regulation on placards, garbage management plans and garbage record-keeping:
  - Every ship of 12 m or more in length overall and fixed or floating platforms shall display placards which notify the crew and passengers of the discharge requirements of regulations 3, 4, 5 and 6 of this Annex, as applicable. The placards shall be written in the working language of the ship's crew and, for ships engaged in voyages to ports or offshore terminals under the jurisdiction of other Parties to the Convention, shall also be in English, French or Spanish.
  - Every ship of 100 gross tonnage and above, and every ship which is certified to carry 15 or more persons, and fixed or floating platforms shall carry a garbage management plan which the crew shall follow.

This plan shall provide written procedures for minimizing, collecting, storing, processing and disposing of garbage, including the use of the equipment on board. It shall also designate the person or persons in charge of carrying out the plan. Such a plan shall be based on the guidelines developed by the Organization2 and written in the working language of the crew.

- Every ship of 400 gross tonnage and above and every ship which is certified to carry 15 or more persons engaged in voyages to ports or offshore terminals under the jurisdiction of another Party to the Convention and every fixed or floating platform shall be provided with a Garbage Record Book
- The competent authority of the Government of a Party to the Convention may inspect the Garbage Record Books or ship's official log–book on board any ship to which this regulation applies while the ship is in its ports or offshore terminals and may make a copy of any entry in those books, and may require the master of the ship to certify that the copy is a true copy of such an entry. Any copy so made, which has been certified by the master of the ship as a true copy of an entry in the ship's Garbage Record Book or ship's official log-book, shall be admissible in any judicial proceedings as evidence of the facts stated in the entry. The inspection of a Garbage Record Book or ship's official log-book and the taking of a
- certified copy by the competent authority under this paragraph shall be performed as expeditiously as possible without causing the ship to be unduly delayed.
- The accidental loss or discharge of fishing gear as provided for in regulations 7.1.3 and 7.1.3bis which poses a significant threat to the marine environment or navigation shall be reported to the State whose flag the ship is entitled to fly, and, where the loss or discharge occurs within waters subject to the jurisdiction of a coastal State, also to that coastal State.

An overview of the types of garbage and whether ships are allowed to discharge waste into the sea is provided in Figure 2 (IMO, 2016).

Figure 2 Simplified overview of discharge provisions MARPOL ANNEX V

Type of garbage	Ships outside special areas	Ships within special areas	Offshore platforms and all ships within 500 m of such platforms
Food waste comminuted or ground	**Discharge permitted** ≥3 nm from the nearest land and en route	**Discharge permitted** ≥12 nm from the nearest land and en route	**Discharge permitted** ≥12 nm from the nearest land
Food waste not comminuted or ground	**Discharge permitted** ≥12 nm from the nearest land and en route	**Discharge prohibited**	**Discharge prohibited**
Cargo residues not considered harmful to the marine environment and not contained in wash water	**Discharge permitted** ≥12 nm from the nearest land and en route	**Discharge prohibited**	**Discharge prohibited**
Cargo residues not considered harmful to the marine environment contained in wash water		**Discharge only permitted in specific circumstances**[1] and ≥12 nm from the nearest land and en route	**Discharge prohibited**
Cargo residues considered harmful to the marine environment	**Discharge prohibited**	**Discharge prohibited**	**Discharge prohibited**
Cleaning agents and Additives[2] contained in cargo hold wash water	**Discharge permitted**	Discharge only permitted in specific circumstances[3] and ≥12 nm from the nearest land and en route	**Discharge prohibited**
Cleaning agents and additives[2] contained in deck and external surfaces wash water		Discharge permitted	**Discharge prohibited**
Carcasses of animals carried on board as cargo and which died during the voyage	**Discharge permitted** as far from the nearest land as possible and en route	**Discharge prohibited**	**Discharge prohibited**
All other garbage including plastics, domestic wastes, cooking oil, incinerator ashes, operational wastes, fishing gear and e-waste	**Discharge prohibited**	**Discharge prohibited**	**Discharge prohibited**
Mixed garbage	When garbage is mixed with or contaminated by other substances prohibited from discharge or having different discharge requirements, the more stringent requirements shall apply.		

Source: (IMO, 2016).

1.4.5 MARPOL ANNEX VI

Regulation 12 in Annex VI describes the ozone-depleting substances. Deliberate emissions of ozone-depleting substances are prohibited. They include emissions occurring during maintenance, service, repair or disposal of systems or equipment. This excludes minimal releases associated with the recapture or recycling of an ozone-depleting substance.

New installations which contain ozone-depleting substances are prohibited on all ships. New installations containing hydro chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

The substances referred to in this regulation, and equipment containing such substances, should be delivered to appropriate reception facilities when removed from ships (IMO, 2006d).

Again, waste arising from Annex VI regulations can be discharged at sea for the purpose of securing the safety of a ship and those on-board and to save a life at sea. It is also allowed to discharge in case of discharge as a result of damage to a ship provided all precautions have been taken.

Annex VI includes a regulation on SO_X emissions (Regulation 14). While ships are within a SECA (SO_X emission control area), the Sulphur content of fuel oil should not exceed 0.1% m/m or an EGCS (exhaust gas cleaning system) should be used. From 2020 onwards, the limit outside ECAs will be 0.5% sulphur m/m. EGCSs produce washwater, which is not waste, and sludge. The latter is not included in the scope of this research because wastes from EGCS have been discussed significantly in the EGCS Sub-Group of the European Sustainable Shipping Forum. Therefore, this study did not audit ships with an EGCS.

Regulation 16 of Annex VI on shipboard incineration allows shipboard incineration only in a shipboard incinerator and each incinerator should be approved by the Administration. Shipboard incineration is prohibited for the following substances:
- MARPOL Annex I, II and III cargo residues and related contaminated packing materials;
- polychlorinated biphenyls (PCBs);
- garbage, as defined in Annex V of the present Convention, containing more than traces of heavy metals; and
- refined petroleum products containing halogen compounds.

Shipboard incineration of polyvinyl chlorides (PVCs) is prohibited, except in shipboard incinerators for which IMO Type Approval Certificates have been issued. Shipboard incineration of sewage sludge and sludge oil generated during the normal operation of a ship may also take place in the main or auxiliary power plant or boilers, but in those cases, shall not take place inside ports, harbours and estuaries.

1.5 Outline of the report

Chapters 2 through 14 provide a review of waste generation, treatment and disposal per type of waste. Each chapter contains a definition of the type of waste, a description of its management on-board ships, technologies to reduce the amount of waste, the drivers for waste generation and an estimate of the quantity of waste. In those cases where any of these issues vary over ship types, a reference is made to specific ship types involved.

Chapter 15 provides an audit of waste notification forms and other observations. Chapter 16 contains the conclusions.

Annex A contains the full references of literature sources. An overview of interviews and ships audited is presented in Annex B. The results from the online survey are presented in Annex C.

2 Oily Bilge Water

2.1 Introduction

Bilge water is a mixture of liquids that are collected in the bilge of a ship. It is made of a mixture of fresh water, sea water, oil, sludge, chemicals and various other fluids that drain into the Bilge. Sea water and fresh water can find its way to the bilge wells due to drainage from the deck, leakage in the pipe lines, leaky pump and valve glands from machinery or spillages in the engine room.
Bilge water is generated through condensation, leakages and cleaning. As a general rule, bilge water contains oil from the engine rooms; hence the term 'oily bilge water'. Any liquid entering the bilge system including bilge wells, bilge piping, tank top or bilge holding tanks is considered to be oily bilge water (Lloyd's Register, 2008). All vessels have oily bilge water, although the quantities for recreational vessels are minimal.

2.2 Oily bilge water management and technology

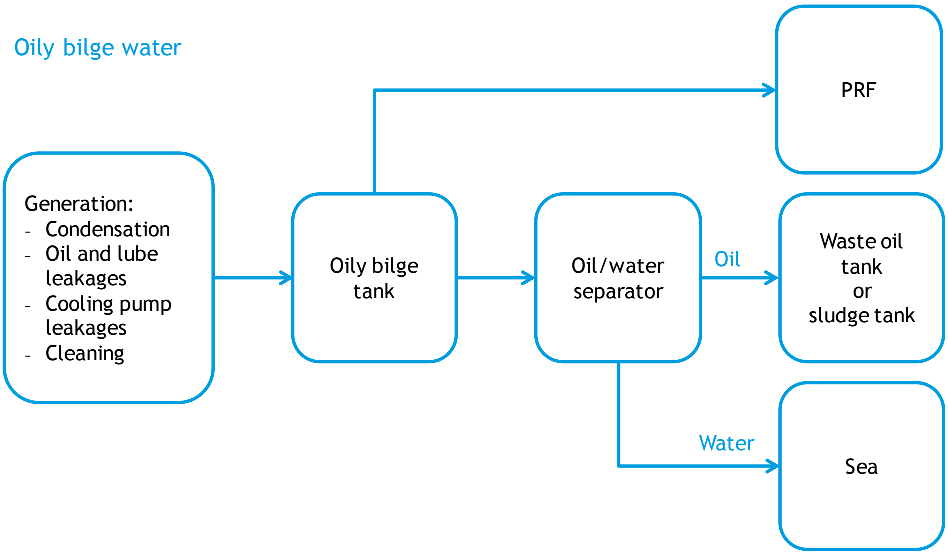
The bilge water can be managed by retaining it on-board in a tank and discharging it to a port reception facility, or it can be treated on-board with an OWS. This on-board treatment system is designed to remove the oily part from the vessel bilge water prior to the discharge of the treated bilge water.

Bilge separator technologies have advanced in recent years to improve the effectiveness of oily bilge water treatment. Most of the tested bilge separators by the US Coast Guard were treatment systems that combined a gravity oil-water separator (OWS) or centrifuge with one or more additional unit operations that 'polish' the bilge water effluent to reduce concentrations of emulsified oil (EPA, 2011). Even though there are several technologies to separate the water and oil, such as absorption/adsorption, biological treatment, coagulation/flocculation, flotation and membranes, the most frequently found technology during the ship audits are the ones based on density differences between oil and water. This type of treatment can reduce the quantity of bilge water by 65–85%.

MARPOL has regulated that all ships over 400 gross tons (GT) are required to have equipment installed on-board that limits the discharge of oil into the oceans to 15 ppm when a ship is en route. They are also required to have an oil content monitor (OCM) and a bilge alarm to detect if the treated bilge water meets the discharge requirements. The system consists of a three-way valve that makes it possible to retain treated bilge water on-board in case the discharge does not comply with the requirements.

Figure 3 presents the waste flow diagram of oily bilge water, based on the ship audits and interviews and confirmed by the internet survey. Oily bilge water is collected in a holding tank (the oily bilge tank) and either disposed of directly to a port reception facility or, more often, treated in an OWS. The clean water is generally discharged to sea. The oil fraction from the oil/water separator is usually fed into a waste oil or sludge tank and treated as such (see also (EPA, 2008); (Friends of the Earth, 2009)).

Figure 3 Waste flow diagram oily bilge water



All the ships audited in this study had some type of OWS treatment system installed. In some cases the OWS system was not operational, as the waste management plan required the ship to retain all generated bilge water on-board until the possibility of discharge to a PRF. In most cases, however, an OWS was used and the water was discharged at sea.

An example of the waste flow for oily bilge waters on-board a ship is presented in Table 3. The ship in the first case study treats part of the oily bilge water generated in an OWS (less than 50%). In this case not all of the oily bilge is delivered in port to PRF, the ship elected to keep some on-board as it has sufficient capacity to store it and deliver it to PRF in the next port (approximately 20%).[3] In the second case study, the ship does not use an OWS but stores the bilge water in a sludge tank and delivers it to PRF in port. The amount that is generated does not have to be the same as the amount disposed, as some bilge water can be stored on-board for delivery to PRF in a port. The third case study is the case of an oil tanker that normally uses an OWS and disposes the water fraction of the oily bilge water at sea. However, in the period of studying the waste flows of this ship, no OWS was used and no discharge was made at sea and no delivery was made to PRF. The amount of bilge water generated in this period was only 25% of the storage capacity. The fourth case study is a ferry which uses settling and an OWS to treat oily bilge water and disposes the water at sea while storing the oil in a dirty oil tank. In this period more bilge water is generated than the storage capacity of 70.2 m^3 thus a large amount is disposed at sea. These examples show that the management of oily bilge water can differ per ship, as well as the amount of waste being treated, disposed at sea or retained on-board for delivery at PRF.

[3] Although the PRF Directive states that ,,.... the European Commission in its "interpretative........" has stated that this should be the next port of call. However if a vessel has sufficient capacity at the next port of call to keep this waste on-board for a subsequent voyage it can re-notify that it wishes to keep this waste on-board through the Advanced Waste Notification Form.

Table 3 Case studies oily bilge water

Type of vessel	Time period	Amount generated	Amount treated in OWS	Amount treated and disposed at sea (only water fraction)	Amount treated and retained in sludge tank (oily fraction)	Amount delivered at PRF from oily bilge tank
A. General Cargo	49 days	11.2	4.5	2.8	1.7	6.3
C. General Cargo	35 days	1.4	0	0		2.0
F. Oil tanker	35 days	4	0	0		0
I. Ferry/Ro-Ro	48 days	167.1	159.4	159.4		0

Note: The amount disposed in a certain period can be larger than the amount generated because the tanks may contain bilge water at the beginning of the period.

2.3 Drivers for oily bilge water generation

Overall, the general policy of the ships visited during this study is to minimise the contamination of bilge water with lubricants, grease, cleaning fluids and other wastes before it accumulates in the lowest part of a vessel. Even so several factors are driving the generation of oil waste. Oily bilge water generation varies and depends on factors such as the size of the ship, engine room design, preventative maintenance, and the age of the components on the ship (EPA, 2008).

When asked, most of the chief engineers interviewed reply that while the overall procedure is to keep the bilge clean in practice the main drivers for oily bilge water generation are condensation and leakages in the engine room. This is determined by the weather conditions and change in temperature as well as by cleaning and maintenance of the machine room.

For yachts, the oily waste is only from lubricating oil and depends on operation hours of the generator and main engine. The online survey indicates other drivers for oily bilge water such as the type of engine, the age of the engine and the type of fuel burnt as well as the engine running hours per day.

2.4 Quantity of oily bilge water generation

Overview of the literature

The reported quantities of oily bilge water vary among type of waste and among ports. An average ship generates 20 m^3 per month of oily bilge water (EMSA, 2008).

Literature provides several estimations of oil waste for cruise ships.
For oily bilge water, a typically large cruise ship will generate an average of 8 metric tons per day. A moderate sized cruise ship with 3,000 people will generate 25,000 gallon (95 m^3) of oily bilge water in a week, equivalent to 3,571 gallon (13.5 m^3) per day (Friends of the Earth, 2009). EPA (2008) provides the daily volume of bilge water production based on ship tonnages (Table 4). These figures could be used to calculate the production per person and per GT. However, no clear relationship with passenger numbers and ship tonnage can be found.

Table 4 **Maximum daily bilge water production**

Ship tonnage	Passenger/crew capacity	Bilge water production (max. m^3/day)
22,000	1,100	4
46,000-48,000	1,500-2,160	11
50,700-55,400	1,850-2,380	19
76,000-78,000	2,700-3,200	10

Source: (EPA, 2008).

Quantitative results from this study

During ship audits and interviews, information on bilge water generation of 19 ships was collected (see Annex B for an overview on data availability). The amounts *generated* per day varied from 0.01 to 13 m^3. The median value in our small sample was 0.3 m^3 per day and most of the ships generate less than 0.5 m^3 per day. This is in line with information gathered during interviews and in the internet survey.

There is a weak correlation of the amounts generated with the size of the ship, which is to be expected because larger ships have larger engine rooms and other areas in which more water vapour can condensate. The amount of oily bilge water generated per 1,000 GT varied from 0.003 to 0.86 m^3/day. The latter value is an outlier; most of the ships generate less than 0.01 m^3 of oily bilge water per 1,000 GT per day and the median value in our small sample was 0.02 m^3 per 1,000 GT per day. There was no correlation with the fuel consumption of the ship.

Literature also provides a wide range of bilge water production and an average of 0.67 m^3 per day which lies within the range of this research.

2.5 Conclusion

Oily bilge water is a type of waste generated during normal operations of the engine room and thus applicable to all types of vessels. The management of oily bilge water can be achieved in two ways, either storage of the bilge water to dispose at a PRF or treatment of the bilge water in an OWS and the subsequent discharge of the separated oil to a PRF and the water to the sea. Oily bilge water can be stored on-board in a holding tank, thus the amount that is disposed is not always the same as the amount being generated as the ship can elect to keep waste on board if it has sufficient capacity for its storage to the next port of call. The generation of oily bilge water depends on several factors, including the size of the ship, the design of the engine room and the age of the engine. The amounts generated per day varied from 0.01 to 13 m^3 (with larger ships generally generating more than smaller ships), the median value in our small sample being 0.3 m^3 per day or 0.02 m^3/1,000 GT per day. The amount can be reduced by 65-85% by using and oil water separator and discharging the water fraction into the sea.

3 Oily Residues (Sludge)

3.1 Introduction

Oil residue (sludge) is the waste from the purification of fuel or lubricating oil or separated waste oil from oil water separators, oil filtering equipment or oil collected in drip trays, and waste hydraulic and lubricating oils (IMO, 2008). In addition to oil or fuel, sludge often contains water, tar, asphalts and other contaminants (both soluble and insoluble matter).

Sludge is generally generated in a fuel or lube oil purifier, which centrifuges the fuel to separate these impurities. This is done to prevent damage to engine components, reduce wear and improve fuel combustion. At regular intervals, the resulting sludge is drained. Fuel from leakages, tank cleanings and, in some cases, the oil fraction from the oil/water separator is also treated as sludge.

All vessels produce sludge, with the possible exception of vessels that run exclusively on distillates (see, however, Section 3.3).

3.2 Oily residues management and technology

Oily residues can be managed on-board by retaining them in a tank and then delivering them to PRF, or they can be treated on-board. The most frequently used technology to treat oily sludge is an incinerator. Prior to incineration a heating system (evaporator) is often used to evaporate the water fraction of the sludge. In some cases, the evaporator is also used just to reduce the amount of sludge.

An incinerator consists of a combustion chamber with a burner unit, a sludge inlet and an electric control panel.

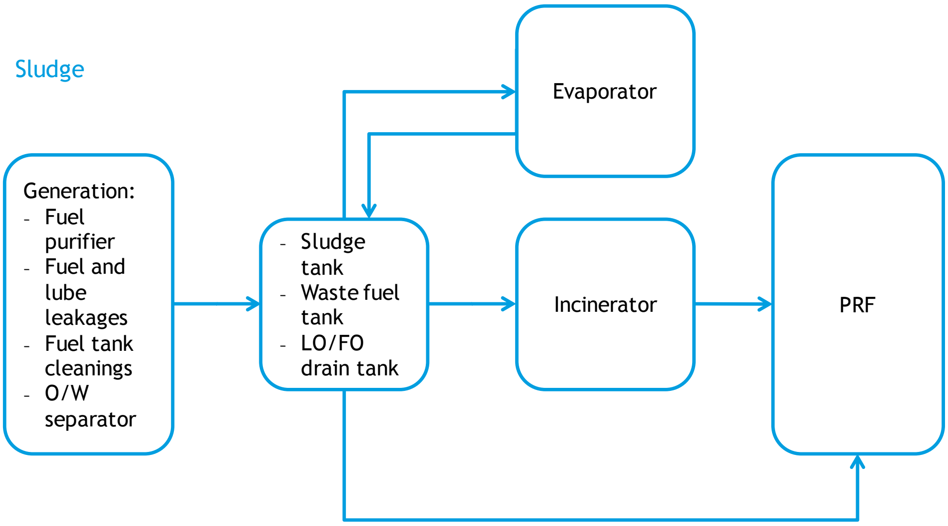
The standard specification for shipboard incinerators intended to incinerate garbage and other shipboard wastes generated during the ship's normal service covers the design, manufacture, performance, operation and testing of incinerators up to 4,000 kW. The standard for type approval of incinerators has recently been reviewed and renewed. See Resolution MEPC.244(66) (MEPC, 2014).

Figure 4 presents the waste flow diagram of sludge. Sludge is generally collected in a sludge tank, a waste fuel tank, a waste oil tank or a lube oil or fuel oil drain tank. It may then be transferred directly from the tank to a port reception facility. In other cases, the quantity is reduced in an evaporator which evaporates water from the sludge. It can also be incinerated on-board, in which case the incinerator ashes are delivered to a PRF.

Many of the ships on which this study has gathered information do not treat oily residues but dispose of them to a PRF. Some ships, especially smaller ships, are not equipped with evaporators and incinerators. Additionally ships that have this equipment do not always use them.

In most cases, the sludge is stored in a sludge tank before delivery to PRF in a port. Sometimes, sludge and oily bilge water are stored in one tank before delivery.

Figure 4 **Waste flow diagram oily residues**



An example of the waste flow on-board different ships is presented in Table 5 below. The first ship is a large bulk carrier that evaporates 50% of the sludge and incinerates 50% and therefore none of the waste is disposed of as sludge (incinerator ashes may be delivered to PRF but they are a different type of waste) during a period of 96 days. This ship has a capacity for storing 43 m^3 of sludge and therefore the untreated sludge was kept on-board. The second ship is a smaller general cargo ship which does not treat the oily sludge and only delivers it to PRF. This ship delivers more than generated in this time period which also indicates that oily sludge has been stored before (0.4 m^3) as it had sufficient storage capacity on board. This ship has a capacity of storing sludge of 20 m^3. The third ship does not treat oily sludge and only delivers this at the PRF. This ship delivers less than is generated, indicating the rest is stored. The storage capacity in the sludge tank is 33.1 m^3.These examples show that oily sludge can be managed in different ways.

Table 5 **Case studies oily residues**

Type of vessel	Time period	Amount generated	Amount treated	Amount delivered at PRF
D. Dry bulk carrier (HFO/MGO)	96 days	25.2 m^3	8.4 m^3	0 m^3
C. General Cargo (MGO)	35 days	1.6 m^3	0 m^3	2 m^3
I. Ferry/Ro-Ro (ULSF)	48 days	48.6 m^3	0 m^3	30 m^3

3.3 Drivers for oily residues generation

The amount of oily residues generated depends on the type and the amount of fuel consumed. Most interviewees indicate that as a rule of thumb, 1-3% of heavy fuel oil is sludge. This has also been found by Maersk Line, who also confirmed that fuel quality is a driver. In addition other drivers have been presented including oily bilge water landed as sludge, increased waste oil production due to machinery failure, leaks, cleaning operations and maintenance jobs. Other technical factors could also affect sludge production for example desludging intervals, back pressure setting on the purifiers, running of a bilge water separator and operating efficiency of various purifiers and filters.[4] The same range applies to ultra-low sulphur fuel oils (fuels with a sulphur content of 0.10% m/m or less that are sold with residual fuel specifications).

We have observed significant differences in the amount of sludge from Marine Gas Oil (MGO). While some ships claim not to produce sludge from MGO and do not use purifiers, others do generate sludge when consuming MGO, although slightly less than in the case of Heavy Fuel Oil (HFO). For ships that can use both MGO and HFO, the price difference between this fuel is a driver for the type of fuel consumption and thus for the generation of sludge.

The amount of sludge from lube oil depends on the type of lube oil and the lube oil consumption. It is generally several orders of magnitude less than oil residues from fuel. Through an automatic lubrication system it is possible to decrease usage by 70% by choosing the exact dosage required for the installation to achieve a sound performance. This enables installations to achieve significant lubricant savings (Netherlands Maritime Technology, 2016).

The amount of fuel consumed is driven by the engine efficiency and the energy demand of the vessel for e.g. propulsion and electric power. As a result of market forces and regulation, the energy efficiency of ships is improving. Market forces have for example resulted in slow steaming, weather routing, et cetera, while the EEDI (Energy Efficiency Design Index) has resulted in an improvement of the energy efficiency of new ships. Lower fuel consumption will result in a lower production of sludge.

3.4 Quantity of oily residues generation

Overview of the literature

A short overview of some quantity indications from literature and the percentage of oily residues of fuel consumption is presented in Table 6.
Data from a selection of Maersk Line container vessels indicated that a range of 21.4 to 71.2 m^3/ of oily residues were produced in the period January to June 2015 (Maersk Line, 2015)The corresponding percentage of fuel consumption is between approximately 0.75% and 4.75%.

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[4] Maersk Line collected data on 19 vessels between January and June 2015. One vessel produced less than 1% sludge and 2 vessels more than 3%. Maersk Line, 2015, Collected data on garbage and sludge generation, Presentation to the ESSF subgroup on PRF.

Table 6 **Overview of oily residue as percentage of fuel consumption**

Type of ship	Oil residue as a % of fuel consumption	Source
Gas	1% of daily fuel consumption	Afcan, 2006
Container ship	1% of daily fuel consumption	Afcan, 2006
Cargo liner	1.1% of daily fuel consumption	Afcan, 2006
Tanker	0.9% of daily fuel consumption	Afcan, 2006
Cruise ships	1-2% of the heavy fuel oil	EPA, 2008
General	1.0-1.5 % of the daily HFO fuel consumption and 0.5 % of the daily MDO fuel consumption	EMSA, 2015

Quantitative results from this study

During ship audits and interviews, information on the oily residue generation of 18 ships was collected. In some cases, fuel purifiers generate a fixed share of sludge, e.g. 1 or 2% of the fuel or lube oil that is purified. In other cases, fuel purifiers generated amounts dependent on the quality of the fuel. The amounts *generated* per day varied from 0.003 to 11.3 m^3. There was a strong correlation with the amount of fuel consumed: most of the ships generated 0.01 to 0.03 m^3 of sludge per tonne of HFO and between 0 and 0.01 m^3 per tonne of MGO, although many indicated during interviews that the amount of sludge generated from MGO was negligible. One audited ship used ultra-low sulphur fuel oils which was said to generate an amount of sludge similar to HFO.

Half of the ships visited had an incinerator installed although this was not always used, e.g. because the costs of heating up the tank are higher than the costs of disposal. In several cases, sludge is heated up in a separated tank before being incinerated to remove the water fraction through evaporation. This can reduce the amount of sludge by up to 75%. Other ships have a management policy to deliver the sludge to a PRF and not use incineration as a disposal route.

Incineration of sludge, either with or without prior use of an evaporator, reduces the volume of waste to 0.5% of the volume of sludge or less. Again, the cost of incineration of sludge can outweigh the cost of disposing the sludge at a port facility. The use of incinerators can be restricted if vessels are trading in purely coastal areas. Moreover, not all incinerators are type-approved to incinerate sludge.

3.5 Conclusion

Oily sludge is residual waste as a result of consuming fuel and is applicable to all types of vessels. The treatment of oily sludge can be achieved through evaporation and or incineration. Most of the sludge is stored and disposed at a PRF without treatment. The generation of oily sludge water depends on several factors, including the type and amount of fuel. Ships generate between 0.01 to 0.03 m^3 of sludge per tonne of HFO and between 0 and 0.01 m^3 per tonne of MGO, although many do not generate sludge when using MGO as a fuel. Ultra-low sulphur fuel oils generate an amount of sludge similar to HFO.

Evaporation can reduce the amount of sludge by up to 75%, while incineration of the remaining sludge reduces the amount by 99% or more.

4 Oily Tank Washings (Slops)

4.1 Introduction

Cargo tanks in oil tankers need to be cleaned before a new cargo is loaded that is not compatible with the previous cargo or before dry-docking. Generally, when lighter oil is loaded after a heavier one, the tank has to be cleaned.

Tank cleaning may be carried our by spraying with crude oil (crude oil washing or COW), with seawater or with fresh water and detergents. The former does not generate waste because the residues are converted to useful cargo.

Oil tank washings (slops) are generated when oil cargo tanks are cleaned with water. They are a mixture of oil, water and dispersants.

4.2 Oily tank washings management and technology

After cleaning their tanks, oil tankers store their washings in a slop or residual tank. Figure 4 presents the waste flow diagram after oily tank washings. After generation and if the voyage is long enough, the slops in the tank are able to settle and the water fraction is discharged to sea in a controlled manner, while the oily fraction is delivered to a PRF.

Under MARPOL Annex 1, regulation 34 provides the possibility for a controlled discharge when a ship is on route, not in a special area and more than 50 nautical miles from shore. The water fraction can be discharged at a maximum of 30 litres per nautical mile. When a ship has an oil discharge monitoring and control system (ODMCS) and a slop tank no further requirements are needed for discharging at sea. In contrast to bilge water discharges to sea no ppm limits are required for discharge of settled slops and consequently oil water separators are not generally used. The total quantity of oil discharged into the sea may not exceed 1/30,000 of the total quantity of the cargo of which the residue was formed for tankers built/delivered after 31 January 1979.

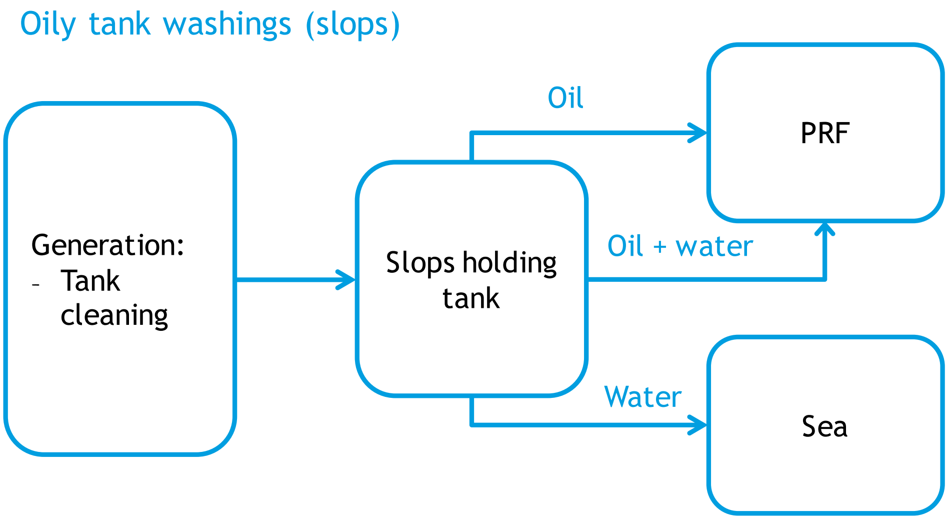
An ODMCS can consist essentially of following the systems (Marineinsight, 2016):

- An Oil content meter: The oil content meter is used to analyse the content of oil in the water that is to be discharged overboard. This oil is expressed in parts per million (PPM).
- A flow meter: The flow rate of the oily water to be discharged is measured at the discharge pipe.
- A computing unit: A computing unit calculates the oil discharge in litres/nautical miles and the total quantity, along with date and time identification.
- An overboard valve control system: The auto control valve is installed at the overboard so that it must close and stop the discharge when permissible limit has been reached.

In other cases, e.g. when the voyage is not long enough for the slops to settle, the contents of the storage tank is delivered to PRF without separating oil and water fractions.

During this study the ships that have been visited that washed their tanks all delivered the slops (partly or wholly) to PRF. One of the ships used an ODM-E (Oil Discharge Monitoring Equipment) to analyse whether the slops contain oil, before discharging at sea. An other gave the whole content of the slops tank to a PRF.

Figure 5 **Waste flow diagram oily tank washings**



An example of the waste flow of two ships is presented in the table below. The first is a large oil tanker that only allows the residue of tanks washings to settle, disposes the water in sea and discharges the slops to PRF. The second ship stores slops on board and delivers it to PRF. These examples show slops can either be disposed or settled and partly discharged. These ships have indicated that there is a large capacity of slop tanks on-board (around 3,000 m^3 for the large tanker and 173 m^3 in the smaller tanker) and that the amount of settling water allowed to be discharged at sea is 30 litres per 1,000 m^3 cargo.

Table 7 **Case studies oily tank washings**

Type of vessel	Time period	Amount generated	Amount treated	Amount delivered at PRF	Amount disposed at sea (water fraction)
F. Oil tanker (large)	240 days	1,291 m^3	0 m^3	1,210 m^3	81 m^3
H. Oil tanker (small)	130 days	550 m^3	0 m^3	550 m^3	0 m^3

4.3 Drivers for oily tank washings generation

The driver of this type of waste is the number of oil tank cleanings and the type of fuel carried.

The volumes of waste depend on the type of cargo and are related to the efficiency of water/oil decanting separation and available areas to discharge the water in sailing route.

4.4 Quantity of oily tank washings

Quantitative results from this study

During ship audits and interviews, information on oily tank washings from 4 ships was collected. The amounts *generated* per tank washing ranged from 60 to 500 m^3 when all the tanks on a ship were washed Relative to the size of the tanks, slops can be up to 2% of loading capacity.

4.5 Conclusion

Oil tank washing only occur on oil tankers. They are generally stored in a settling tank after which the water is discharged at sea and the oil is delivered to PRF. Some technologies are available to reduce and monitor slops, although in practice it is often settled and delivered at the port.
The amount of slops generated depends on several factors, including the number of tank cleanings and the size of the tanks. The amount can range from 60 to 500 m^3 for a ship and up to 2% of the loading capacity per tank.

5 Sewage

5.1 Introduction

Sewage is defined as drainage and other wastes from any form of toilets and urinals; drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; or other waste waters when mixed with the drainages defined above (IMO, 2006b). This is generally referred to as 'black water'. It does not include grey water which is the drainage generated from dishwasher, showers, laundry, bath and washbasin drains (MEPC, 2012).

The discharge of sewage into the sea is prohibited under MARPOL IV, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land. Sewage which is not comminuted or disinfected may be discharged at a distance of more than 12 nautical miles from the nearest land.

Within the Baltic Sea, a special area under MARPOL Annex IV, discharge of sewage from passenger ships is only permitted the ship has in operation an approved sewage treatment plant which meets specific nitrogen and phosphorus removal standards and which has been certified by the Administration.

5.2 Sewage management and technology

A holding tank is usually the minimum system that a ship has on-board. The size of the tank should take into account the capacity for the retention of all sewage, the operation of the ship, the number of persons on-board and other relevant factors. The holding tank shall have a means to indicate visually the amount of its contents.

A ship using an approved a sewage comminuting and disinfecting system shall be fitted with facilities for the temporary storage of sewage when the ship is less than 3 nautical miles from the nearest land. This type of on-board treatment system uses a physical/chemical-based system that relies on reducing the size of sewage and chlorination.

There are several types of approved sewage treatment plants. The most common is an on-board treatment system that uses biological or aerobic digestion based system (thus a mix of primary and secondary treatment), which consists of three compartments. The first chamber is similar to conventional septic tanks, where solids settle to the bottom and scum floats to the top. In the second compartment, the aeration chamber, the partially clarified wastewater is mixed with air to assist bacteria to further break down solids. In the third compartment further settling of solids and final chlorination for disinfection is added.

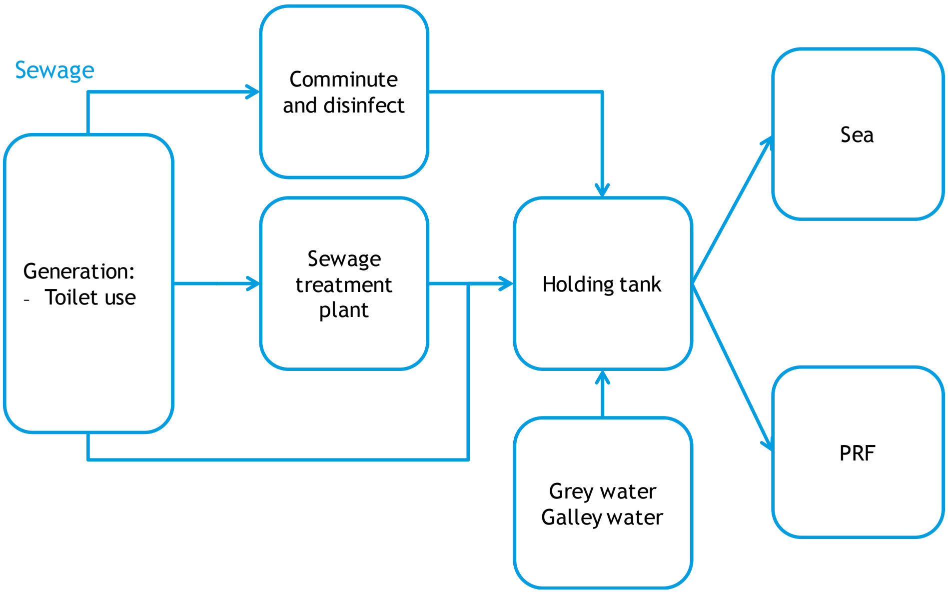
Most ships visited during this study had one or a combination of the systems described above. However, in one case a ship did not have a holding tank and the sewage was discharged immediately after treatment in the sewage treatment plant.

Figure 6 presents the waste flow diagram of sewage. Sewage can be either collected in a holding tank, comminuted and disinfected, or treated in a sewage treatment plant. The effluent of the sewage treatment plant is either discharged directly to the sea or kept in a holding tank. Ships that do not have a sewage treatment plant collect the black water in a holding tank.
The holding tank can also be used to collect grey water and/or galley water. However, grey water is not always routed to the holding tank and sometimes stored in dedicated holding tanks. Grey water can sometimes be discharged directly into the sea or mixed with sewage to be treated. It can also be recycled into the toilet flushing system.

Roughly a quarter of cruise ships have Advanced Wastewater Treatment System (AWTS) installed which mix and treat grey and black water producing a bio-residual or sewage sludge that needs to be retained for discharge ashore (HELCOM, 2013). In cruise ships it is common to have a separated tank for galley water, which is discharged in accordance with the regulations for food waste. For cruise ships it is common to comminute, mix and disinfect the water prior to discharge to the sea.

The ship audits show that most of the ships have a treatment plant on-board and only a few disinfect the sewage. These are predominately smaller and older vessels. Most of the time, the treated effluent is discharged in the open sea.

Figure 6 Waste flow diagram sewage



An example from the ship audits is presented in Table 8. The first is a chemical tanker with a crew of 24 people. On this ship sewage is being disinfected and treated in a type approved sewage treatment plant.
If the ship is in the port, all of the generated effluent is delivered to PRF in the port and on the route all is continuously discharged at sea as this ship does not have a holding tank. The second ship is a ferry that has a crew of 152 people and 1,360 passengers. On this ship sewage is treated in a type approved sewage treatment plant (only 37 m^3 in this case, the remainder is grey water). The third ship also treats the sewage in a treatment plant and discharges directly after treatment and disinfection. These examples show the different ways of managing sewage effluent and the difference between types of vessels.

Table 8 **Case studies sewage**

Type of vessel	Time period	Amount generated	Amount treated	Amount delivered at PRF	Amount disposed at sea
E. Chemical tanker	Daily	3-4 m^3	1 m^3	All during stay	Continuous disposal on route
I. Ferry/Ro-Ro	Monthly	1,900 m^3	37 m^3	0 m^3	1,900 m^3
D. Dry bulk carrier	Daily	3 m^3	3 m^3	0 m^3	3 m^3

5.3 Drivers for sewage generation

The main drivers for the amount of sewage are:
- the number of crew members and passengers;
- the type of toilets: water toilets produce larger amounts of sewage than vacuum toilets;
- length of voyage;
- type of treatment: the presence of a sewage treatment plant, or comminuting and disinfection system provides different quantities of waste.

5.4 Quantity of sewage generation

Overview of the literature

The generation and collection of sewage has also been reported by several ports in their waste management plan. The port of Dudinka (Russia) has estimated an annual waste volume of both bilge waters and sewage to be 352.8 m^3 for 110 calls at the port (MMPA, 2012). The port of Durres (Albania) estimated a generation of 4,354.9 m^3 grey & black water in 2012 (TEN ECOPORT, 2014). The port of Tallinn (Estonia) received in 2014 a total of 11,211 m^3 of sewage based on 7,624 ships (Environmental Board, 2015).
The port of Igoumenitsa (Greece) reports for passenger vessels in 2011 a total quantity of sewage of 6.3 m^3 (Beza, et al., 2014). The quantity of sewage waste from in 2010 for over 26 EU ports was reported to be approx. 1,250,000 m^3 (Ramboll, 2012).

The amount of sewage wastewater generation depends on the size of the ship and the type of technology used. Table 9 provides differing numbers among ship types and technologies.

Table 9 Overview of quantities of sewage per type of ship

Type of ship	Type of technology	Amount generated	Amount treated	Time period	Source
Cruise ship	Type II MSD (Marine Sewage Device) or AWTS	30,000 gallons (114 m^3) per person	4,000 gallons (15 m^3) of sewage sludge per day	1 week	Friends of the Earth, 2009
Cruise	AWTS	1.1-27 gallon (0.004-0.1 m^3) per person	17 gallons (0.06 m^3) per person	Per day	EPA, 2008
Ferries		0.1 m^3 sewage per person		Per day	HELCOM, 2014
Fishing	The Tank MSD®	5.5 gallons (0.02 m^3) of black water generated per person		Per day	OCNMS, 2011
	Ahead Tank®	9.2 gallons (0.03 m^3) of black water generated per person		Per day	OCNMS, 2011
	Orca®	30 gallons (0.11 m^3) of black water generated per person		Per day	OCNMS, 2011

Quantitative results from this study

During ship audits and interviews, information on waste water and sewage of 11 ships was collected. In addition, information was received from interviews and the internet survey. The main reason for the small number is that quantities are not recorded or monitored, but have to be estimated from the amount of water consumed or from the number of days it takes for the holding tank to fill. For the same reason, it is not always possible to distinguish between sewage (black water) and other waste waters. The amounts of waste water *generated* per day varied from 0.4 to 700 m^3. The amount of sewage depends on the number of passengers and the toilet type (vacuum toilets generate less black water than water closets). The amounts generated per day per person varied from 0.01 to 0.45 m^3. Of this quantity, 0.01 to 0.06 m^3 is probably black water, and the remainder grey or galley water as some ships mix these in sewage holding tanks. The range of waste generated is comparable to the values found in literature, although the upper value is higher.

5.5 Conclusion

Sewage is treated in different ways and if well treated can be disposed at sea. The amount of sewage effluent generated depends on for example the number of people on-board and the type of system used. The amount of waste water generated is estimated to be between 0.04 and 0.45 m^3 per day per person. Of this quantity, 0.01 to 0.06 m^3 is probably black water, and the remainder grey or galley water.

6 Plastics

6.1 Introduction

Plastic waste can be generated in all types of vessels and often originates from domestic provisions and supplies used for operations on board the ship.

Plastic waste typically comprises sheets, wrapping, bottles, drums, synthetic ropes, synthetic fishing nets, plastic garbage bags and empty chemical cans.

In some cases ships and waste handlers distinguish plastics that have been in contact with food ('contaminated' or 'dirty') and 'clean' plastics.
The two are kept separate for hygienic reasons and because dirty plastics (and other food waste) may contain pathogens and may need to be disposed differently by the port.

6.2 Plastic management and technology

There are two ways to manage plastics on-board, either they are kept separately (compacted or otherwise) and delivered to PRF or they can be incinerated, the ashes being treated as incinerator ashes. Incineration is constrained by MARPOL VI, Regulation 16 which prohibits shipboard incineration of polyvinyl chlorides (PVC) except in a shipboard incinerator for which an IMO Type Approval Certificates has been issued in accordance with MEPC.244(66) (MEPC, 2014) (see also Chapter 10). Incineration of plastics with PCBs is always prohibited.

The ship audits and interviews have shown that the ship crew often doesn't have expertise to assess the type of plastic they are handling, and therefore chose not to incinerate plastics at all. If plastics are incinerated without knowledge of the type of plastics, the ashes may be liable to laboratory analysis before delivery is permitted and the costs of delivery and subsequent disposal will rise. The ships audited in this study that had an on-board incinerator, did therefore not incinerate plastic.

Consequently, the basic handling method for plastic on-board the vessels included in this study was to keep it separately (in combination with minimization) until it can be delivered to PRF. For the prevention of the amount of plastic waste produced by drinking bottles, desalination by Reverse Osmosis (RO) has proven to be a reliable and economical means of drinking water production on ships. This could prevent the amount of plastic waste from drinking bottles[5].

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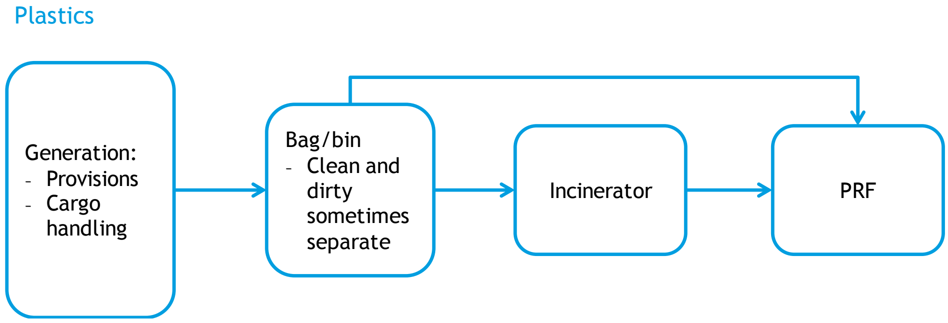
5 More information on the cost analysis and technology can be found in for example: Guler et al. 2015 (COST ANALYSIS OF SEAWATER DESALINATION USING AN INTEGRATED REVERSE OSMOSIS SYSTEM ON A CRUISE SHIP) and Abdella 1994 (Reverse Osmosis Desalination).

Ships with large amounts of plastics, such as cruise ships can use a crusher or compactor to minimize the volume of the waste, since the delivery to PRF is often based on the volume. Other cargo ships often crush these containers by hand to minimize their volume.

Figure 7 presents the waste flow diagram of plastic waste. Plastics are often generated by hoteling and cargo handling. Plastics are collected in bags or bins. Sometimes clean and dirty plastics are collected separately, especially when they are to be delivered to different PRF. They can be incinerated when the ship incinerator is certified for this use. Even though most garbage management plans aim for prevention of plastic waste when provisions are taken in, it is often not realized because of practical reasons, e.g. because plastics are part of the supplies and supplies are unpacked well after delivery so the plastics cannot be returned to the supplier.

Figure 7 Waste flow diagram plastic waste



Four examples from the ship audits are presented in Table 10. The first is a general cargo ship that incinerates a share of the plastic waste (about 50%). The second ship is a chemical tanker that does not treat but only stores plastic waste. The waste is delivered to PRF in European ports as other ports are expensive or PRFs are not available. The third ship has a compactor and delivers the plastic waste to PRF. An incinerator is not used as it is not known which plastic can be burnt. Sometimes the volume of plastic waste is large because there is no time to compact it. The fourth ship does not treat the waste, but collects the recyclable plastic separately and delivers this to recycling companies on shore. These examples show the different ways of managing and the factors influencing the place of disposal.

Table 10 Case studies plastics

Type of vessel	Time period	Amount generated	Amount incinerated	Amount delivered at PRF
A. General cargo	90 days	8.1 m^3	4 m^3	4.1 m^3
E. Chemical tanker	70 days	13.54 m^3	0 m^3	13.5 m^3
G. Bulk carrier	130 days	18.24 m^3	0 m^3	18.24 m^3
I. Ferry/Ro-Ro	60 days	43.5 m^3	0 m^3	43.5 m^3

6.3 Drivers for plastics generation

The generation of garbage, including plastics, on ships depends on several factors. The amount of hoteling waste is based on the number of passengers and crew, and consumption of material and is proportional to the standard of living (EPA, 2008). In practice, provisions, packaging and galley waste mainly drive the generation of plastics. Plastic waste from cargo handling is limited to general cargo and depends entirely on the type and packaging of the cargo. In addition, waste reduction before loading can affect the amount of plastic waste generation on-board, for example of plastic packaging is removed before loaded on-board.

The online survey indicates that the generation of plastic depends on several factors such as the trading area, supplier, policy of the companies buying and selling provisions and supplies, and the goods delivered to the ship.

6.4 Quantity of plastics generation

Overview of the literature

There is very little information available at the current time on the actual volumes of plastic waste generated on ships and often this is provided as figures for garbage or solid waste. According to the literature each person generates 1 kg of solid waste daily and other sources provide an estimation of 3 kg/day per crew member (Beza, et al., 2014). Solid waste related to maintenance is 11 kg/vessel-day for all ships (NEA; PM Group, 2009). These estimations are not for plastic waste specifically but provide a range of 0.06 to 0.2 m^3 per person per day and 0.7 per day[6] (Cantin, et al., 1999)

Quantitative results from this study

During ship audits and interviews, information on plastic waste of 14 ships was collected. The amounts *generated* per day varied from 0.001 to 8.2 m^3. The amounts per crew member day varied from 0.001 to 0.016 m^3. We consider the latter value an outlier due to rounding of the quantity of waste in the garbage record book. Most of the observations are between 0.001 and 0.008 m^3 per crew member per day, with an average of 0.006 m^3 per crew member per day. In interviews and in the online surveys, quantities of up to 0.025 m^3 per person per day were suggested. This is only possible if large amounts of operational wastes are plastics.

The range of waste per person per day is comparable with the literature values for solid waste, although with a smaller lower limit.

6 Assuming a density of 16 kg/m^3 taken from: (Cantin, et al., 1999)

6.5 Conclusion

Plastic waste is mostly generated from packaging and is often stored and delivered to PRF. It is possible to compact and incinerate plastic although this is not often done in practice. The generation of plastic waste depends on several factors including the number of people on-board, as well as the type of cargo. It can also depend on the policy and operational practices of suppliers. Most ships generate between 0.001 and 0.008 m^3 of plastics per person per day, although in a few cases quantities up to 0.025 m^3 per person per day have been reported.

7 Food Wastes

7.1 Introduction

Food waste is a generated on all kinds of vessels in the galley and or in the restaurant. IMO defines this as any spoiled or unspoiled food substances and includes fruits, vegetables, dairy products, poultry, meat products and food scraps generated on board ship. However, on-board of large vessels (cargo and cruise ships) a distinction is sometimes made between soft organic food waste (peels, leftovers, etc.) on the one hand and hard organic (bones) and packaging on the other (even though packaging is not food waste according to MARPOL Annex V). This separation is not based on regulation, but originates from practical management on board of ships.

7.2 Food waste management and technologies

Organic food waste can be directly discharged into the sea 12 nm from the nearest land , or comminuted and then discharged into the at sea 3 nm from the nearest land (12 m in special areas). Alternatively food waste can be stored on-board separately for later disposal at sea or delivery to PRF in case disposal at sea is not allowed due to regulation. The guidelines for implementation of Annex V describes that precaution must be taken so that plastics that are contaminated by food wastes (e.g. plastic food wrappers) and other garbage is not discharged into the sea together with other food wastes.

The regulation prescribes that in all cases, garbage should be stored in a manner which avoids health and safety hazards. The following points should be considered when selecting procedures for storing garbage:

- Food wastes and other garbage to be delivered to PRF and which may carry diseases or pests should be stored in tightly covered containers and be kept separate from garbage which does not contain such food wastes. Quarantine arrangements in some countries may require double bagging of this type of waste. Both types of garbage should be stored in separate clearly marked containers to avoid incorrect discharge and facilitate proper handling and treatment on land.
- Cleaning and disinfecting are both preventative and remedial pest control methods that should be applied regularly in garbage storage areas (MEPC, 2012).

Ships that generate much food waste (e.g. cruise ships or work ships) sometimes dry it to reduce its volume and diminish the risk of putrefaction (Tidy Planet, 2015).
Other ships, such as large yachts are often equipped with cooled waste storage rooms where they can keep the food waste until they reach the next marina or port to prevent odour and for disease control.

During the ships visits there was a practical difference found between large ships (more than 20 crew members) and smaller ships regarding the discharge management. Smaller ships tend to discharge the food waste in accordance with relevant regulations by manually emptying the food waste bins in the sea. Larger ships with more galley waste tend to distinguish soft and hard organic waste. Usually a communiter or shredder is integrated in the sink.

The food waste (soft parts) are comminuted or shredded while adding fresh water and flushed through the piping system to a galley tank or a greywater sewage tank until it can be disposed at sea.

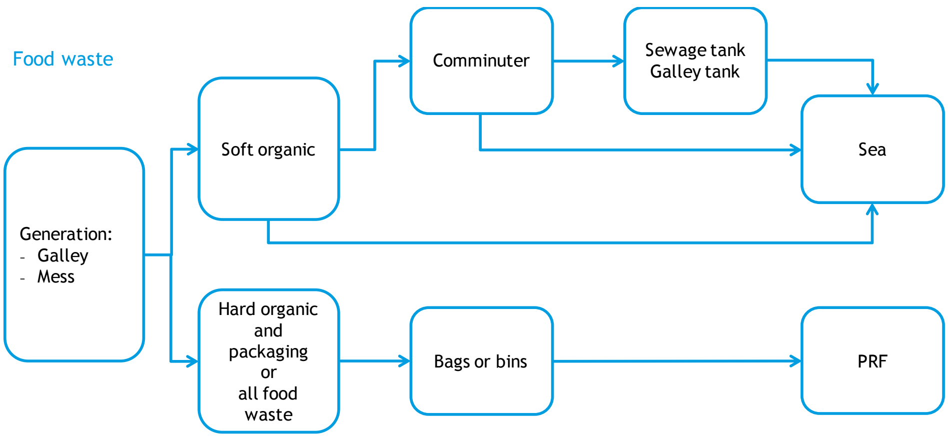
Hard organic waste, waste from plates and packages are collected in bags and bins and disposed at port reception facilities (see also (Mohammed, et al., 1998); (EPA, 2008)). In some cases this is delivered under category of domestic waste instead of food waste. No difference was found between cruise ships and normal cargo ships regarding the food waste management. The exception is that cruise ships tend to have a galley waste tank, which is discharged following the same regulation as food waste and/or as grey water.

The survey showed that in some passenger ships, the food waste is sometimes dried and incinerated. However, we have not come across this in the ship audits or interviews undertaken in this study.

The ships included in this study often passed the food waste through a grinder or shredded the food waste on-board and discharged it to the sea where permitted. Other ships included in the study collected their food waste in bins and delivered it to PRF.

Figure 8 presents the waste flow diagram for food waste.

Figure 8 Waste flow diagram food waste



An example from four ships audited is presented in Table 11. The first ship is a passenger ship that grinds the food waste and disposes part of the generated waste to sea (about 2%) and disposes the rest to PRF (98%) On this ship, food waste is often disposed at sea with galley water. The second ship is a bulk carrier that does not treat the food waste and only disposes in open sea (about 40%) or delivers it to PRF (about 60%). The third ship comminutes the food waste and stores the waste in separate bins. Half of the waste is disposed at sea while the other half is delivered to PRF. The fourth ship uses a shredder, although it is usually disposes waste at sea beyond the 12 nm limit which means no treatment is required. These examples show that different types of ship manage food waste in different ways and that they generate different volumes.

Table 11 Case studies food waste

Type of vessel	Time period	Amount generated	Amount treated	Amount delivered at PRF	Amount disposed at sea
V. Passenger ship	21 days	181 m^3	4 m^3	177 m^3	4 m^3
G. Bulk carrier	130 days	4.11 m^3	0 m^3	1.70 m^3	2.40 m^3
D. Dry bulk carrier	140 days	2.75 m^3	1.42 m^3	1.33 m^3	1.42 m^3
A. General cargo vessel	90 days	1.25 m^3	1.15 m^3	0.1 m^3	1.15 m^3

7.3 Drivers for food waste generation

The amount of food waste generated is driven by the number of crew or passengers and the efficient management of provisions.

7.4 Quantity of food waste generation

Overview of the literature

The literature provides a few case studies for food waste as presented in Table 12.

Table 12 Food waste estimations

Type of vessel	Food waste generated	Sources
Cruise ship	12 m^3 of food waste per vessel per week	(EPA, 2008)
Work vessel	175 kgs/0.35 m^3 of waste per week (0.3 kg per person per day)	(Tidy Planet, 2015)
Cruise ship	3.5 kg per passenger per day	(HPTI, 2007)
Cruise ship	18 to 32 kg foods and drinks per person per week	(ASCI, 2000)

Quantitative results from this study

During ship audits and interviews, information on food waste of 13 ships was collected. In some ships the food waste was passed through a grinder or shredded, which reduces the volume while in others it was collected in bins for delivery to PRF in the port.

The amounts *generated* per day varied from 0.002 to 8.6 m^3. For passenger ships the amount ranged from 0.001 to 0.002 m^{3}/person/day and for cargo ships from 0.001 to 0.016 m^3/person/day. The higher values are probably inaccurate as they are the result of rounding in the garbage record book. In one case, a bucket of food waste was thrown overboard each day and routinely recorded as 0.1 m^3, even though the bucket was only 10 litres and often not completely full. Most of the ships report values between 0.001 and 0.003 m^3 /person/day (in the internet survey and interviews, much higher values have been mentioned, up to 0.018 m^3 per person per day. We consider this to be unrealistic, given the low values for cruise vessels).

The average amount of food waste generated per ship per day according to literature could be approximately 2 m^3 per day, which lies within the (wide) range provided by this research.

7.5 Conclusion

Food waste can be managed in different ways, either by being comminuted, shredded or passed though a grinder and afterwards disposed at sea or by being collected in bins and delivered to PRF. This depends on the policy of the ship and the generation of waste depends on other factors such as the amount of crew and passengers on-board and storage of food waste on-board. The ship audits show that the amounts of food waste generated varied from 0.001 to 0.003 m^3 per person per day.

8 Domestic Wastes

8.1 Introduction

Domestic waste is all waste from domestic spaces on-board of the ship that is not food waste, cooking oil or plastic. IMO defines this as “all types of waste not covered by other Annexes that are generated in the accommodation spaces on board the ship. Domestic wastes does not include grey water” Domestic waste therefore typically comprises paper, cardboard, fluorescent lamps, synthetic material, foils, metal cans, lids, glass, pantry packaging waste et cetera. Domestic waste is generated on-board as a consequence of crew and passenger hoteling and is generated on all types of vessels.

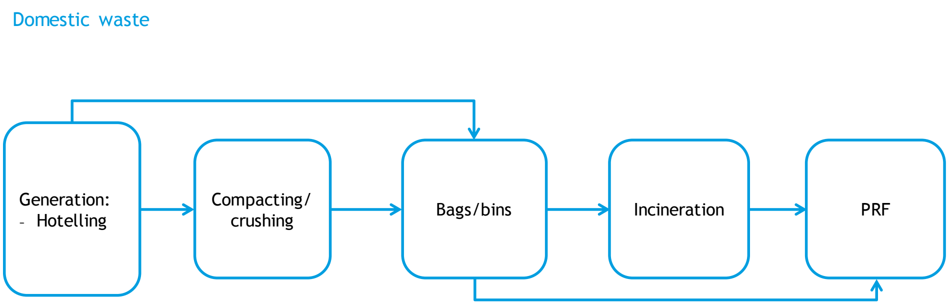
8.2 Domestic waste management and technology

Treatment of domestic waste differs depending on what types are generated and the amount of waste generated. The following treatments were found during this study: glass crusher, compactor for several types of waste such as cans and tins, and incineration of paper and cardboard. Incineration of paper and cardboard occurs on most ships that have an incinerator (cargo and passenger). Waste minimisation measures are mostly found in cruise ships to reduce the amounts generated in the domestic areas.

Figure 9 presents the waste flow diagram for domestic waste. After collection, domestic waste is sometimes compacted or crushed and stored in bags or bins. Several ships that were visited collected paper and cardboard, fluorescent lamps, metals and glass separately. Sometimes, these are delivered to PRF, however, sometimes paper and cardboard is incinerated and then the ashes are delivered to PRF.

Most of the ships included in this study stored their domestic waste and delivered it to PRF. Some used a compactor or incineration, especially for certain types of waste such as cardboards and paper.

Figure 9 Waste flow diagram domestic waste



Three examples from the ships included in this study are presented in Table 13. The first ship is a cargo ship that incinerates part of its domestic waste (76%) and delivers the remainder to PRF. The second ship is a bulk carrier which does not treat domestic waste but delivers it all to PRF. The third ship usually incinerates cardboard, oily rags and paper. In the period studied 70% of the generated domestic waste was incinerated and the remaining was delivered to PRF. These examples indicate amounts for treated and untreated domestic waste.

Table 13 **Case studies domestic waste**

Type of vessel	Time period	Amount generated	Amount incinerated	Amount delivered at PRF	Amount disposed at sea
A. General cargo	90 days	10.20 m^3	7.80 m^3	2.40 m^3	0 m^3
D. Bulk carrier	140 days	7.50 m^3	0 m^3	7.50 m^3	0 m^3
F. Oil tanker	112 days	3.45 m^3	2.45 m^3	0.6 m^3	0 m^3

8.3 Drivers for domestic waste generation

The interviews and ship visits show that domestic waste can consist of inorganic household waste such as cartons, cans, paper, glass and other scrap material. The main drivers are the number of crew and passengers and the types of products used by crew and passengers.

The survey provides some additional drivers such as food cultures, for example some countries eat mostly rice packaged in plastic, while others eat individual prepared meals. The generation of this type of waste can vary every month.

8.4 Quantity of domestic waste generation

Overview of the literature

(EPA, 2008) find that on average, each cruise ship passenger generates at least 2 pounds (900 grams) of non-hazardous solid waste per day. In addition, each cruise ship passenger disposes of two bottles and two cans (both of which are recyclable) per day (EPA, 2008). For passenger ships, the average domestic waste generation is 3 kg/person/day (NEA; PM Group, 2009). Assuming an average density of 75 kg/m^3, this translates into 0.04 m^3/person/day.[7]

In total, domestic waste production for cargo vessels is 2 kg/person/day (NEA; PM Group, 2009) or 1.4 kg/person/day (EMSA, 2015). This translates into 0.02–0.03 m^3/person/day.

[7] The average density is based on the average density of uncompacted co-mingled plastic bottles, news & pams, cardboard and mixed cans in UK municipal waste (70 kg/m^3) and of co-mingled plastic bottles, news & pams, cardboard, mixed cans and glass (84 kg/m^3). WRAP, 2010: www.wrap.org.uk/sites/files/wrap/Bulk%20Density%20Summary%20Report%20-%20Jan2010.pdf

Quantitative results from this study

During ship audits and interviews, information on food waste of 14 ships was collected. Some of the ships visited incinerated or compacted some of the waste while others stored domestic waste and delivered it to PRF.

The amounts *generated* per day on the ships studied varied from 0.001 to 8 m^3. The amounts per crew member day varied from 0.001 to 0.02 m^3, which was confirmed in the internet survey. For passenger vessels the amount ranged from 0.0004 to 0.002 m^3 per person per day. The average amount of waste production per day from the literature lies within the range provided in this study.

8.5 Conclusion

Domestic waste consists of different types of products and is generated by crew and passenger hoteling. Domestic waste is often stored on-board and disposed in the port. It is also possible to compact or incinerate part of the domestic waste. The main drivers for generation of domestic waste are the number of people on-board and the type of products used by them. The ship audits provide a range of domestic waste generation per day per person of 0.001 to 0.02 m^3, which is confirmed by the online survey.

9 Cooking Oil

9.1 Introduction

Cooking oil waste is generated on-board during food preparation and is generated on most types of vessels.

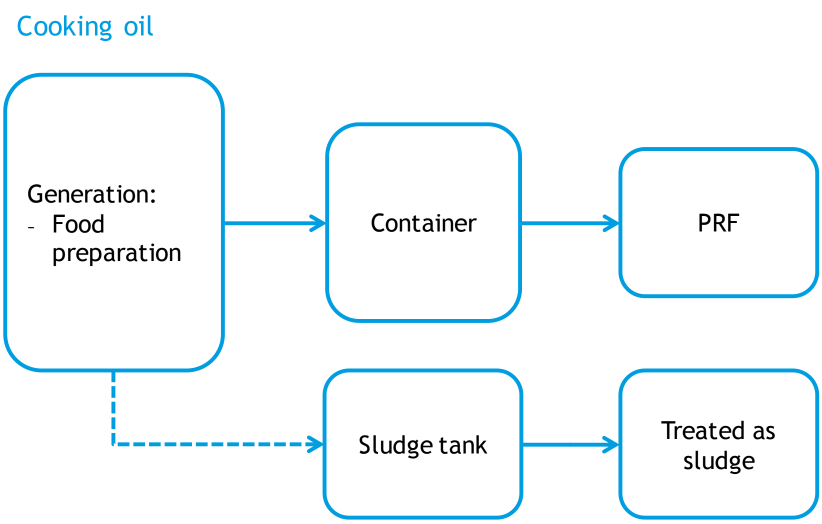
9.2 Cooking oil management and technology

Cooking oil is in most cases collected and delivered to PRF. In some cases it is incinerated. On some ships, it used to be customary to mix the cooking oil with sludge and treat it as sludge. However, MEPC 68 decided that this was not in line with MARPOL Annex V (MEPC 68/21 paragraph 12.14 (MEPC, 2015)

Large cruise liners tend to have separate tank for the storage of cooking oil with large capacities (up to 1,000 m^3). The used oil is sold when in port and can be used for e.g. biofuel production.

Figure 10 presents the waste flow diagram of cooking oil based on the interviews, ship audits, the internet survey and a review of garbage management plans. Generally, cooking oil is generated during food preparation, stored into a container and delivered to PRF. Despite the regulation prohibiting it, the ship audits showed that not all crew are aware of this regulation and cooking oil is still mixed with sludge.

Figure 10 Waste flow diagram cooking oil



Three examples from the ships visited during this study are presented in Table 14. The first ship is a bulk carrier that adds cooking oil to the oily bilge tank and incinerates it as sludge. All generated cooking oil waste is incinerated and nothing is delivered ashore. The second ship is an oil tanker that only collects its cooking oil and delivers it to PRF. The third ship is a passenger ship which generates a larger amount of cooking oil. These examples give an indication of the figures along the waste flow diagram of cooking oil.

Table 14 Case studies cooking oil

Type of vessel	Time period	Amount generated	Amount disposed in sludge tank	Amount delivered at PRF	Amount disposed at sea
G. Bulk carrier	130 days	0.14 m^3	0.14 m^3	0 m^3	0 m^3
H. Oil tanker	94 days	0.13 m^3	0 m^3	0.13 m^3	0 m^3
V. Passenger ship	21 days	1 m^3	0 m^3	1 m^3	0 m^3

9.3 Drivers for cooking oil generation

The main driver for generation of cooking oil is the amount of food that is fried, the number of passengers and crew member on-board and the duration of the voyage.

9.4 Quantity of cooking oil generation

Quantitative results from this study

During ship audits and interviews, information on the cooking oil waste of 8 ships was collected. Only a few ships treat cooking oil, with the majority storing and delivering it to PRF. The amounts recorded in the garbage record book on these 8 ships varied from 0.004 to 0.14 m^3 per day. The latter is incredibly high and could be due to misreporting (e.g. recording litres instead of m^3). The amounts per crew member day varied from 0.04 to 0.08 litres (ignoring the one outlier discussed above). For passenger vessels this figure increase to 0.01 litres per person per day, however during the study there are not many observations for this type of vessel.

9.5 Conclusion

Cooking oil a waste type generated on-board during food preparation and is often stored and disposed to PRF. In practice it can also be treated as sludge although this is not allowed under MARPOL Annex V. The main driver is the type of food being prepared and the number of people on-board. The ship audits provide a range of cooking oil generation from 0.01 to 0.08 litres per person per day.

10 Incinerator Ashes

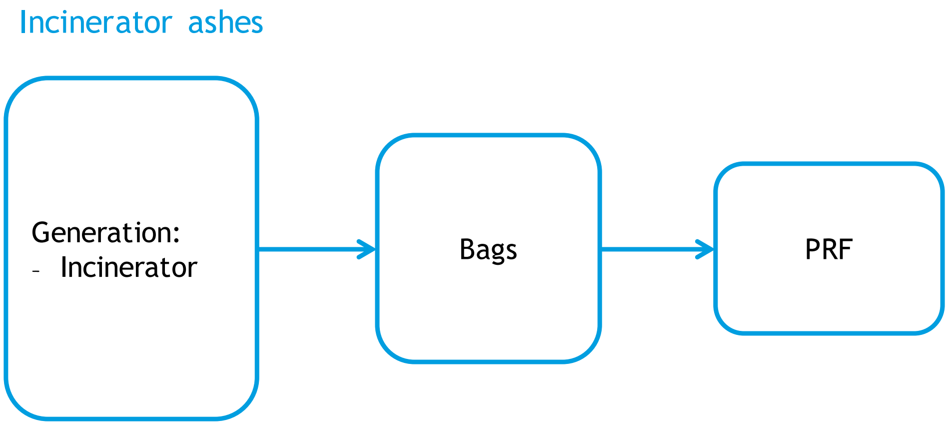
10.1 Introduction

Ships can be equipped with incinerators to burn sludge, domestic, operational waste and other types of waste. The resulting incinerator ashes are reported separately in the garbage record book.

10.2 Incinerator ashes management and technology

Figure 11 presents the waste flow diagram of incinerator ashes. Ashes are generated in the incinerator, collected in bags and delivered to PRF. There is no further treatment of this waste. The bags or bins are often dedicated for incinerator ashes, which may be classified as hazardous waste.

Figure 11 Waste flow diagram incinerator ashes



Examples from two ships visited during this study are presented in Table 15. The first ship is a relatively small bulk carrier that incinerates oily sludge. The second ship is a large bulk carrier that incinerates domestic waste and oil sludge. These examples display the figures for the short waste flow diagram for incineration ashes for a large and a small vessel.

Table 15 Case studies incineration ashes

Type of vessel	Time period	Amount generated	Amount treated	Amount delivered at PRF	Amount disposed at sea
D. Bulk carrier	140 days	0.02 m^3	0 m^3	0.02 m^3	0 m^3
G. Bulk carrier	130 days	0.24 m^3	0 m^3	0.24 m^3	0 m^3

10.3 Drivers for incineration ashes generation

The driver for generation of incineration ashes is the amount of incineration of oily sludge (including the oily part of bilge water), plastics, domestic waste including cardboard and operational wastes including oily rags on-board a vessel.

There is a large variety in incinerator use. While some ships incinerate most of their sludge and domestic waste, others have a waste management plan that prohibits the use of an incinerator.

If a ship has an incinerator installed, it is common practice to use it for treatment of oily sludge. From the ships visited 6 out of 13 had an incinerator, although these were not always used. The choice to have an incinerator installed depends on the route of the ship, the duration of the voyage, the waste storage capacity on-board the ship and or the overall waste management policies on the ship.

The use of the incinerator on one of the ships in this study was related to cost reduction for the ship when it visited EU ports. The management explained that oily sludge may be delivered free of charge at Chinese and African ports. Therefore to reduce costs in EU ports the sludge was incinerated before arriving in the EU so that no more sludge would be delivered to the PRF than could be done for free. In another case a ship was bought containing an incinerator, but the new management decided to remove it as the company's operating procedure was to deliver all types of waste to PRF.

The use of the incinerator also requires fuel which is an additional cost. Furthermore, the use of an incinerator could be seen as not environmentally friendly which means ships will not get a high ranking in the Clean Shipping Index (CSI). The scoring in the CSI depends on several environmental indicators, such as CO_2 and water and waste control. For the latter, there should be no incinerator on board or documentation of no incineration of garbage and sludge oil (Clean Shipping Index, ongoing).

The type of waste that is burnt in on-board incinerators differs per ship.
The ships included in this study mostly use the incinerator to burn domestic waste and garbage (paper, plastics, etc.) and in a few cases oily sludge.
An example of the latter from the ships included in this study is a bulk carrier with an incinerator for sludge. In a period of 96 days, the ORB shows that the incinerator was used 7 times and in total 4 m^3 was incinerated, while 25 m^3 was generated in this period (so approximately 20% is incinerated).
The garbage record book shows that for a period of 140 day, 0.02 m^3 incineration ashes were disposed to PRF, which means that assuming that no other incineration has taken place, the waste volume has been reduced from 4 m^3 to 0.02 m^3.

The survey has identified some additional drivers that can be mentioned.
In some ports or countries (e.g. Antwerp, Cape Town), independent companies used to buy oily residues and oily sludge from vessels to process and sell it.
The market for sludge has become smaller as the oil price has decreased.
If ship trades only in coastal areas, the use of the incinerator is restricted so the waste that would normally be incinerated will have to be delivered to PRF.

10.4 Quantity of incineration ashes generation

Quantitative results from this study

During ship audits and interviews, information on incineration ashes produced by 4 ships was collected. The type of waste and the amount of waste that is being incinerated differs among the ships visited. The amounts *generated* per month varied from 0.004 to 0.06 m^3.

10.5 Conclusion

Incineration ashes only occur if a ship uses an incinerator, which can be used for garbage and or sludge incineration. The ashes are collected in bags and disposed at a PRF. The use of an incinerator depends on management plans but also on the cost of delivery of the ashes to PRF outside the EU and the cost of fuel used in the incinerator. In coastal areas the use of an incinerator is restricted. The quantities from ship visits provide a range of small generation rates between 0.004 and 0.06 m^3 per month, although this depends entirely on the frequency of incinerator use.

11 Operational Wastes

11.1 Introduction

Many different types of waste are classified as ‘operational wastes’. Most ships include waste from the machine room in this category, such as oily rags and batteries, but can also include other wastes resulting from operation of the ship, such as old ropes, jerry cans, wood, washing machines, scrap, refrigerators, aerosols, ladders, fireworks and flares, chemical remains, asbestos and paint. Therefore, some of this waste should be classified as hazardous material. Some ships also report waste related to cargo handling in this category, such as wooden pallets, stowage material and rubber gloves. On other ships, the category is used for other domestic wastes, such as fluorescent tubes, torn working clothes, etc.

Often, as in the IMO MARPOL Annex V text, the definition of operational waste on-board ship is waste that is not classified elsewhere. To be precise: “Operational wastes means all solid wastes (including slurries) not covered by other Annexes that are collected on board during normal maintenance or operations of a ship, or used for cargo stowage and handling. This includes cleaning agents and additives contained in cargo hold and external wash water but not grey water, bilge water, or other similar discharges essential to the operation of a ship, taking into account the guidelines developed by the Organization” (IMO, 2011).

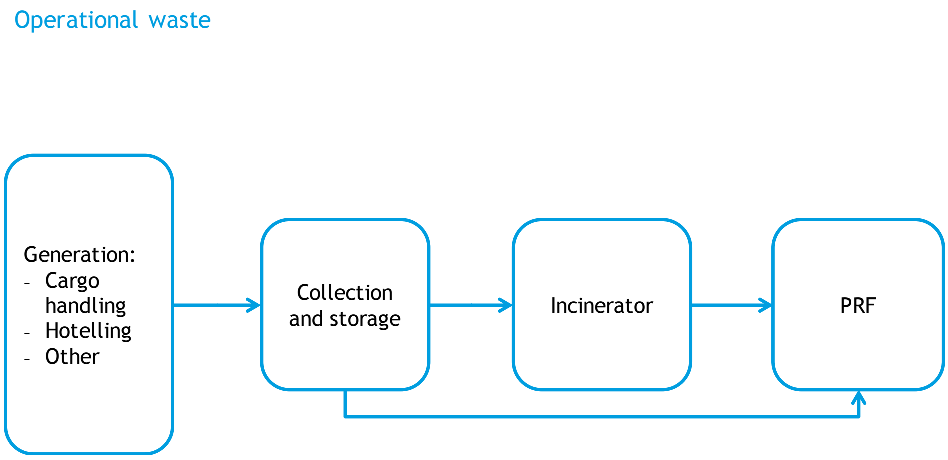
11.2 Operational waste management and technologies

Figure 12 presents the waste flow diagram for operational waste based on the interviews, ship visits and analysis of the garbage management plans undertaken in this study. Operational waste, however defined, is collected and stored. Often, different types of waste (glass, paper, metals) are segregated and stored separately. Hazardous waste is also often also kept separately in certified containers. In some cases operational waste is incinerated as legally appropriate, in other cases it is delivered to PRF.

Occasionally, the amount of operational waste delivered to a PRF is reduced by recycling and re-using. For instance through a ‘Life, For Life’ service, rope is being reused for research or recycled into new products. In this programme, the rope is tested before reusing and recycling to ensure that ropes are not replaced prematurely, thus enhancing sustainable rope management.

Most of the ships included in this study did not treat the operational waste and only stored it on-board before delivering it to PRF. A few incinerated oily rags and cardboard and one indicated plastics and paper are compacted.

Figure 12 **Waste flow diagram operational waste**



Three examples from the ships included in this study are presented in Table 16. The first ship is a bulk carrier that incinerates part of its operational waste (more than 60%) and delivers the rest to PRF. The second ship does not treat the operational waste but delivers it all to PRF. The third ship only incinerates oily rags and delivers the rest to PRF including the ashes.
This ship incinerates a large proportion of the operational waste it generates. These examples show the range in waste amounts being produced and the differences in management of waste and quantities.

Table 16 **Case studies operational waste**

Type of vessel	Time period	Amount generated	Amount incinerated	Amount delivered at PRF	Amount disposed at sea
D. Dry Bulk carrier	140 days	0.08 m^3	0.05 m^3	0.03 m^3	0 m^3
F. Oil tanker	112 days	0.6 m^3	0 m^3	0.6 m^3	0 m^3
E. Chemical tanker	90 days	1.39 m^3	1.09 m^3	0.3 m^3	0 m^3

11.3 Drivers for operational waste generation

Drivers for the generation of operational waste could not be established because of the many different interpretations of the term. Even so, the main driver is the replacement of operational materials due to breakage (or fatigue), end of life or safety legislation. Maersk line found several parameters affecting the volume of garbage as a whole, including discharge after dry-docking, local regulation and laws that provide landing of certain waste, and the storage of waste. The volume of waste is also affected by whether or not it is compacted and if so, how. The respondents from the online survey suggest that the amount of waste generated depends on the size of the ship, as well as the vessels trading area, cargo and how operational waste is defined.

11.4 Quantity of operational waste generation

Quantitative results from this study

During the ship audits and interviews, information on operational waste of 6 ships was collected. Many ships do not report any waste under this category. The amounts *generated* per month varied from 0.02 to 18.6 m^3. The amounts per crew member day varied from 0.001 to 0.1 m^3. Other estimations range from 0.001 m^3 per person per day to up to 0.5 m^3 per person per day, depending on the size of the ship and the voyages undertaken.

11.5 Conclusion

Operation waste can be defined in different waste, which means that there might be some overlap with other types of waste. Operational waste can be stored and/or incinerated before being delivered at a PRF. In practice, mainly oily rags, cardboard and wood are incinerated and in many cases operational waste is collected and not treated on board. The generation depends on several factors such as the size of the ship, as well as the ship's trading area and type of cargo. The ship audits provide a range of 0.001 to 0.1 m^3 per person per day.

12 Cargo Residues

12.1 Introduction

MARPOL Annex V defines cargo residues as 'the remnants of any cargo which are not covered by other Annexes to the present Convention and which remain on the deck or in holds following loading or unloading, including loading and unloading excess or spillage, whether in wet or dry condition or entrained in wash water but does not include cargo dust remaining on the deck after sweeping or dust on the external surfaces of the ship' (IMO, 2011).

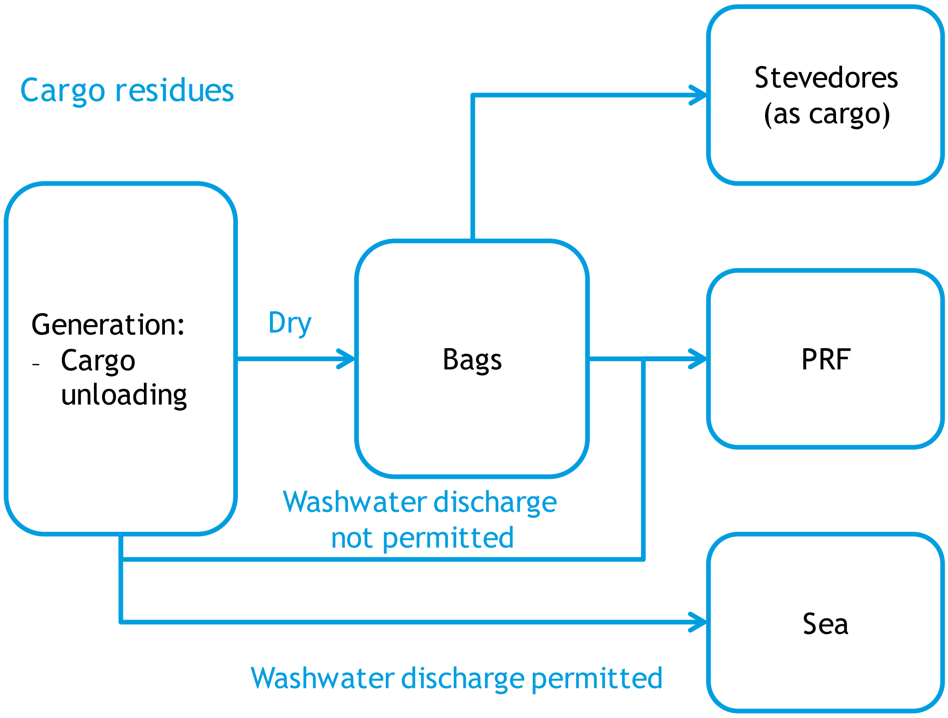
Residues of oil cargoes are covered by MARPOL Annex I and residues of chemical cargoes by Annex II so they are not included in the above definition. Hence, this type of waste is generated on dry bulk carriers and occasionally on general cargo carriers when they transport dry cargoes in bulk. Cargo residues can be left in the corners of the holds or in other places that are not accessible during unloading and very much depend on the efficiency and methods used in unloading the cargo.

12.2 Cargo residues management

Figure 13 presents the waste flow diagram for cargo residues. In general, unloading is done as efficiently as possible to prevent generation of cargo residues. After unloading, cargo holds are brushed or washed (usually by hand) and residues are collected in bags and either handled by the stevedores (as cargo) or delivered to PRF (as waste).
If needed, the cargo holds are rinsed with seawater and the residues disposed of at sea, if discharge is permitted, or to PRF, if it is not.

The information from ship visits indicates that often the waste goes to stevedores or PRF. Some ships have indicated disposal at sea, but this relates to the disposal of washing water.

Figure 13 Waste flow diagram cargo residues



An example of a ship with cargo residues included in this study is a bulk carrier. This ship generated 6.3 m^3 solid cargo residues during the carriage of three different types of cargo. This amount was collected by the stevedore and therefore it was not registered in the GRB. In addition, over a period of 140 days, this ship discharged 3.3 m^3 water containing cargo residues to the sea during the voyage.

12.3 Drivers for cargo residues generation

The amount of cargo residues generated depends on the type of vessel, the type of cargo, the securing and care of the cargo and the handling of the cargo in port (Palabıyık, 2003). The survey identified other drivers, such as cleaning standards and the shape of vessels holds, bulkhead and recesses.

12.4 Quantity of cargo residues generation

Literature provides several quantifications of cargo residues for different types of vessels, of which an overview is presented in Table 17.

Table 17 Cargo residues per type of vessel

Type of vessel	Generation rate	Source
Break bulk cargo	0.81% of break bulk cargo received	NEA, 2009
Dry bulk cargo	0.01% of dry bulk cargo received	NEA, 2009
Bulk carriers	8.2 kg/day	Palabryik, 2003
General cargo vessel	49.3 kg/day	Palabryik, 2003

Quantitative results from this study

Discharge of cargo residues to the sea, incineration and delivery to PRF has to be recorded in the GRB. No recording is required if the waste is collected by the stevedores and not delivered to PRF.

During the ship audits and interviews undertaken as part of this study, information on cargo residues was only found for one ship indicating that, on average, 2.1 m^3 solid waste was generated per discharge of cargo (see above). In the records of the same ship it was found that between 0.5 and 2.8 m^3 of washwater was discharged at sea per washing of the holds. The interviews and the online survey have indicated that the amount of waste generated may range from 0.001% of the cargo to up to 2% of the cargo.

12.5 Conclusion

Cargo residues are only generated on cargo ships (mainly dry bulk carriers) and are often delivered to PRF or stevedores, while washwater is often discharged in sea. The amount generated depends on several factors such as the type of cargo, the handling equipment and the efficiency of the stevedores.
The quantities vary widely from almost nothing to 2% of the cargo.

13 Ozone Depleting Substances

13.1 Introduction

MARPOL Annex VI defines ozone depleting substances as controlled substances defined in paragraph 4 of article 1 of the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, listed in Annexes A, B, C or E to the said Protocol in force at the time of application or interpretation of this Annex. This includes for example Halon 1211, Halon 1301, Halon 2402, CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115 (IMO, 2006d).

Ozone depleting substances are used on-board ships in air conditioning appliances or cooling equipment on reefers. They can also be contained in mobile equipment (fridges, mobile air conditioners). Ozone depleting substance waste is generated on different types of vessels, depending on the presence of appliances and technologies that emit this type of waste.

13.2 Ozone depleting substances management

The generation of ozone depleting substance waste depends on the type of cooling and refrigeration systems on-board ships and the maintenance schedule of these technologies. Ozone depleting substance waste is generated during system checks, repair of leakages or/and annual survey of the systems. Some ships such as yachts have little waste production due to the use of AC and refrigerators with more ozone friendly gases.

Ozone depleting substances which are released to the atmosphere during leakages cannot be collected. Ozone depleting substances that are replaced during maintenance are collected by the specialist engineer undertaking the maintenance work and removed as waste. The major source of non-controlled ozone depleting substance waste is in broken mobile equipment that the ship wants to deliver to PRF.

In the ship audits and interviews conducted for this study, ozone depleting substance waste was not identified. This is probably because major refurbishments of cooling systems, which would require these systems to be drained of ozone depleting substances, do not occur at sea. Also, equipment containing ozone depleting substances may not be classified as ozone depleting substance waste but rather as operational or domestic waste.

13.3 Quantity of ozone depleting substance waste generation

Quantitative results from this study

During ship audits and interviews, information ODS leakages and refillings (which is strictly speaking not waste) was only found for three vessels, one has reported a monthly average generation of 0.83 kg and the other reported 15.9 kg per month on average. A third has reported a monthly average generation of 95 kg, which is about 5% of the weight of the system on this passenger ship.

There is not much information in the literature to compare these values with. As there is not much information from the ship visits or literature, this type of waste was not been validated in the online survey.

13.4 Conclusion

Equipment containing ozone depleting substances produce ozone depleting substances when being refurbished, however this is likely to be taken away by the specialist companies undertaking this repair. The major source of non-controlled ozone depleting substance waste is in broken mobile cooling of refrigeration equipment that the ship delivers to PRF. However, this waste may be classified as operational or domestic waste, and not as ozone depleting substances waste.

It has proven difficult to provide a range of waste generation on-board ships for this type of waste.

14 Other Non-common Waste Streams

14.1 Dirty ballast water

Ballast water is carried in ships' ballast tanks to improve stability, balance and trim. When oil tanks are used to carry ballast water, the water is contaminated with oil and is classified as waste in MARPOL Annex I (IMO, 2006a). We have not identified ships that generate oily ballast water and hence have not analysed this type of waste further.

The production of oily ballast water on a ship is a very rare occurrence. The likely waste arising from ballast water operations on a ship is when sediment in a ballast water tank may have to be removed during a Port State Control tank integrity survey in a port, or when the vessel has to treat its ballast water and cannot do so. Both of these circumstances are very rare and in the event of these circumstances happening, ports are likely to provide the ship with contacts of specialist waste contractors to handle this waste.

14.2 Animal carcasses

Animal carcasses are the remains of deceased livestock. As shown in Figure 2, discharge of animal carcasses is only allowed outside special areas and as far from the nearest land as possible and en route. So the option for disposal of animal carcasses are either discharge into sea or delivery to a PRF. When the ship has an appropriate storage area on board, limited quantities of carcasses may be stored for short periods before discharge. If there are health and safety threats, it is recommended to discharge into sea however more than 12 nm from the nearest land. Before discharge into sea, animal carcasses should be split or treated in order to facilitate the sinking or dispersal of the carcasses (IMO, 2012). We have not identified ships that generate animal carcasses and hence have not analysed this type of waste.

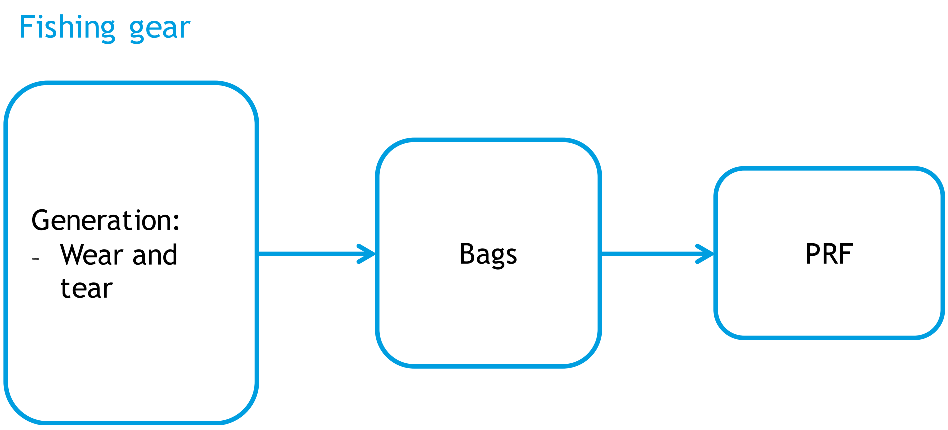
14.3 Fishing gear

Fishing gear waste is generated when fishing gear wears and tears beyond repair. It is only generated on fishing vessels.

14.3.1 Fishing gear waste management

Figure 14 presents the waste flow diagram for fishing gear. Gear that cannot be repaired is generally collected in bags and disposed of in ports, although it also ends up in the sea (Eunomia, 2016). It is also possible to recycle the fishing gear waste into new packaging as done in Skagen (Handson tv/e, 2004).

Figure 14 Waste flow diagram cargo residues



14.3.2 Drivers for fishing gear waste generation

For fishing gear it is reasonable to assume that the quantity of waste produced is directly related to the level of fishing and farming effort (Eunomia, 2016). In practice, the generation of fishing gear waste differs per day and location.

14.3.3 Quantity of fishing gear waste generation

The waste estimated per tonne of fish farmed or captured in Norway is 1 kg plastic from fishing nets and trawl equipment per tonne of output production and 11 kg plastic waste from aquaculture per tonne of output (Eunomia, 2016).

14.3.4 Quantitative results from this study

During ship audits and interviews, information on this type of waste was not found.

15 Observations on Waste Handling

15.1 Introduction

This chapter presents the results of an analysis of waste notification forms in Section 15.2 and some observations made during ship visits in Section 15.3.

15.2 Waste notification forms

We have audited 40 waste notification forms and compared them with the amounts of waste actually delivered to a port reception facility.

The total amount of MARPOL Annex I (IMO, 2006a) waste notified for delivery of all ships in our sample was close to the total amount landed (85-135% of the notified amount was landed). In some specific cases ships actually delivered ranges from 25% of the notified amount to 200% of the notified amount per ship. Case studies showed several reasons for the difference:

- In some cases the oil record book was not updated quickly enough and the amount notified wasn't accurate.
- A discharge on sea of bilge water through an OWS was done after the notification was done.
- The ship notified the port that a set amount of oily waste was to be kept on-board, but was ordered after the notification to deliver it to PRF by a port state control inspector.
- Waste notification forms are sent to port a few days prior to arrival, so they are based on estimates of the amount of waste generated during the time period between drafting the WNF and entry in port. These estimates may be inaccurate.

For MARPOL Annex IV (IMO, 2006b) the amount of sewage notified and delivered differs depending on local regulations. As most ships have a treatment plant, no sewage is stored on-board. The delivery to PRF only occurs when a port does not allow the discharge of treated sewage into the port, or when the ship does not have the technology to discharge raw or treated water into the sea in line with MARPOL Annex IV regulations. Notification does not often happen as sewage is treated and not kept on-board. In some cases raw sewage, treated sewage and wastewater from sewage plants is kept in storage tanks when it cannot be legally discharged under MARPOL Annex IV for subsequent discharge at sea or delivery to PRF.

The total amount of MARPOL Annex V (IMO, 2006c) waste notified for delivery differs strongly from what was actually landed and ranges between 20% and 1,800% of the notified amount. The big difference between notified and landed could be partly due to:

- The waste notification forms are often prepared a few days in advance, while a big part of the generation of garbage is related to the provisions obtained once the ship enters the port. If all the packaging material is delivered before departing, this amount of garbage may not be notified.

- Records kept for garbage are unlike those for MARPOL Annex I (IMO, 2006a) as they focus on the quantities delivered rather than the quantities on board. The quantities of garbage on-board are often estimated by the responsible crew member through a visual inspection. If the amount of garbage exceeds the storage capacity, then this estimation is difficult to make.
- The amount of cargo residues is generated during the discharge and washing of cargo holds (after the notification). In case that cargo residues were on-board when the notification is made, no record is kept of amounts, so estimations may not be accurate.

In general the following observations were made:
- crews do not appear to have a strong incentive to provide accurate estimates of waste in the waste notification forms;
- often the notification is done by the agent and the information flow is handled by several people between the ship/ agent and the National Single Window/the port/the PRF. Mistakes can easily be made;.

The notification form differs from port to port and from ship to ship as ports tend to have a need for detailed information, which is specific for their own situation; and
- The quantities of garbage differ in units, from Kg to m^3 depending on how it's notified and reported when landed. A comparison cannot always be made.
- Waste that is landed at stevedores is not registered.

15.3 Other observations

Prevention of waste

Although many garbage management plans state that their aim is to prevent waste, we have not come across a concrete strategy for waste prevention in shipping companies. Agents interviewed have not been approached with requests to reduce the amount of packaging or otherwise prevent waste from forming on ships. In addition ship suppliers do not take back packaging material, and in fact this type of domestic waste is often not generated in port but at sea, when the crew has more time to unpack supplies.

Even though many ships have a water purifier on-board, the crew often prefers bottled water. Plastic bottles and packaging material constitute the largest share of plastic waste.

Waste classification

The classification of waste is sometimes not clear, especially in the case of 'operational waste'. Domestic waste 'not in any other category' is sometimes recorded as operational waste, while other ships limit this category to wastes directly relating to the operation of the ship (e.g. ropes, pallets, empty paint tins, etc.).

There is a mismatch between the classification of waste in MARPOL Annex V (IMO, 2006c), the classification used on-board ships and the classification used by waste handlers. For example:
- waste handlers insist on separating clean and dirty plastics. Both are in the same category in MARPOL Annex V (IMO, 2006c);
- paper, glass and fluorescent tubes are often collected separately, while they all classify as 'domestic waste' in MARPOL Annex V (IMO, 2006c).

Different classifications may be the cause of misreporting or of errors in entries in the garbage record book.

Ashes that are generated during the incineration of oily sludge are not always recorded in the oil record book. Sometimes, but not always, they are recorded in the garbage record book and sometimes there is no record of these ashes in anywhere. Similarly, ashes that are generated from the incineration of domestic wastes are sometimes recorded in the oil record book and not in the garbage record book.

Recording

The amount of generated waste under MARPOL Annex I is easily followed by the records entered into the oil record book, due to inclusion of a weekly report of the amount of waste in the tanks. The amount of waste under MARPOL Annex V is much harder to predict as the Garbage Record Book only registers the amount incinerated, discharged at sea or landed to PRF.
No weekly report of the amount of garbage on board is kept, in synergy with MARPOL Annex I.

Mixing of different types of waste

On many ships, cooking oil (IMO, 2006c) has traditionally been disposed in the sludge tank (MARPOL Annex I) and treated as sludge. MEPC 68 (MEPC, 2015) decided that this was not in line with MARPOL Annex V (IMO, 2006c), and that cooking oil should be kept separate. This has, however, not been implemented on all ships.

A similar situation of mixing different types of waste occurs on ships that add the galley water and/or ground food waste (MARPOL Annex V) to the sewage tank (MARPOL Annex IV) and then release the combined waste to the sea.

Delivery of waste to PRF

Shipping companies appear to optimize their waste delivery in order to reduce the cost of waste management. Some ships indicate that waste is separated on a ship but the company that collects the waste does not separate this.
In addition, the separation categories of waste can differ among countries.
Some companies have indicated that the storage capacity on board can be expanded by using bags for excess waste.

16 Conclusions

16.1 Waste estimations per type of waste

For almost every type of waste, there is a variety of waste flows and treatment methods. The empirical evidence gathered in this study shows that ships use different treatment methods and often only treat part of a waste stream. All this results in a difference between the amounts of waste generated and the amounts landed.

Table 18 presents a summary of the results of the empirical analysis.

Table 18 Overview of the amounts of waste generated, drivers and treatment methods

Type of waste	Generation rate	Driver	On-board treatment
Oily bilge water	0.01-13 m^3 per day, larger ships generate larger quantities.	Condensation and leakages in the engine room; size of the ship.	The amount can be reduced by 65-85% by using an oil water separator and discharging the water fraction into the sea.
Oily residues (sludge)	0.01 to 0.03 m^3 of sludge per tonne of HFO. 0 and 0.01 m^3 per tonne of MGO.	Type of fuel; fuel consumption.	Evaporation can reduce the amount of sludge by up to 75%. Incineration can reduce the amount of sludge by 99% or more.
Tank washings (slops)	20 to hundreds of m^3.	Number of tank cleanings; Size of loading capacity.	After settling, the water fraction may be discharged at sea.
Sewage	0.01 to 0.06 m^3 per person per day. Sewage is sometimes mixed with other waste water. The total amount ranges from 0.04 to 0.45 m^3 per day per person.	Number of persons on-board; type of toilets; length of voyage.	Effluent from treatment plants is often discharged at sea where permitted under MARPOL Annex V.
Plastics	0.001 to 0.008 m^3 of plastics per person per day.	Number of person on-board.	Often not incinerated. Dirty plastics (plastics that have been in contact with food) are often treated as a separate waste stream.
Food wastes	0.001 to 0.003 m^3 per person per day	Number of persons on-board; provisions	Where permitted under MARPOL Annex V, food waste is often discharged at sea.

Type of waste	Generation rate	Driver	On-board treatment
Domestic wastes	0.001 to 0.02 m^3 per day per person.	Number of persons on-board; type of products used.	
Cooking oil	0.01 to 0.08 litres per person per day.	Number of persons on-board; type of food prepared.	Although not permitted, cooking oil is sometimes still added to the sludge tank.
Incinerator ashes	0.004 and 0.06 m^3 per month.	Use of incinerator; cost of using incinerator.	The incinerator is not used for all types of waste, mostly for paper sometimes for oily sludge.
Operational wastes	0.001 to 0.1 m^3 per person.per day.	Size of the ship; type of cargo.	
Cargo residues	0.001-2 % of cargo load.	Type of cargo. Size of ship.	

16.2 Key findings waste notification form audits

Waste notification forms are prepared before entering a port and are often inaccurate because the amounts generated between the submission of the form and the entry of the port need to be estimated. Also, there does not appear to be a strong incentive for accurate notification. Even with the format in the guidance for PRF providers and users (MEPC.1/Circ.834) waste notification forms can differ from port to port. Ports tend to have a need for detailed information, which is specific for their own situation. Waste that is landed at stevedores is not registered; only waste that is delivered at PRF and at sea.

The amount notified and landed for MARPOL Annex I waste were quite accurate, with a range between 85-135%. But the amounts notified and landed for MARPOL Annex V differ between 20% and 600%.

16.3 Treatment systems

No new on-board technologies were found during the ships visits for the treatment of SGW for MARPOL Annexes I, IV and V waste streams.
The standards under MARPOL are met by the current technologies and are sufficient for the aim of the policies. During the MARPOL discussions at the IMO no new legislation has been discussed since the revision of MARPOL Annex V. The focus for the development of new on-board technologies lies with new legislation regarding air pollution and ballast water. The only expected short-term topic regarding MARPOL Annex V is on-board treatment and the discharge of cargo residues and wash waters of bulk carriers. This might have implications for the development of new technologies in the future.

16.4 Classification of waste

The classification of waste in MARPOL does not always match the practice on board.

Operational waste and domestic waste are overlapping categories and it is often not clear to the crew how certain wastes should be classified. The same holds for galley and restaurant waste that contains plastics, tins and other packaging material in addition to food waste.

Likewise, the MARPOL classification does not always reflect the categories of waste handlers. Waste handlers often insist on keeping clean and dirty plastics separately, for example, even though they are one category under MARPOL.

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Annex B Overview interviews and audits

Table 19 Data availability per type of ship

Type of vessel	Ship audit (interview + ORB/GRB)	Interview including ORB/ GRB	Interview without ORB/GRB
A. General cargo vessel	X		
B. Chemical tanker / oil tanker	X		
C. General cargo vessel	X		
D. Dry bulk carrier	X		
E. Chemical tanker	X		
F. Oil tanker	X		
G. Bulk carrier	X		
H. Oil tanker	X		
I. Ferry/Ro-Ro	X		
J. Container/gas carrier			X
K. Container vessel			X
L. Container vessel			X
M. Roro/Ropax			X
N. Container/bulk carrier			X
O. Container/oil tanker			X
P. Ferry			X
Q. Fishing vessel			X
R. Cargo vessel/oil tanker	X		
S. Car carrier/oil tanker	X		
T. Cargo ship	X		
U. Container ship	X		
V. Passenger vessel		X	
W. Yacht			X
X. Yacht			X
Sum	13	11	

Table 20 Data availability per type of waste

Type of vessel	Oily bilge water	Oily residues (sludge)	Oily tank washings	Oily ballast water	Scale & sludge tank cleaning	Sewage	Plastics	Food wastes	Domestic wastes	Cooking oil	Incineration ashes	Operational wastes	Cargo residues	Animal carcasses	Fishing gear	Ozone depleting substances
A. General cargo vessel	X	X					X	X	X		X					
B. Chemical tanker/oil tanker																
C. General cargo vessel	X	X				X	X	X	X	X						
D. Dry bulk carrier	X	X				X	X	X	X	X	X	X	X			
E. Chemical tanker	X	X				X	X	X	X	X	X	X				X
F. Oil tanker	X	X	X			X	X	X	X	X	X	X				X
G. Bulk carrier	X	X				X	X	X	X	X	X	X				
H. Oil tanker	X	X	X				X	X	X	X		X				
I. Ferry/Ro-Ro	X	X				X	X	X	X	X		X				X

Type of vessel	Oily bilge water	Oily residues (sludge)	Oily tank washings	Oily ballast water	Scale & sludge tank cleaning	Sewage	Plastics	Food wastes	Domestic wastes	Cooking oil	Incineration ashes	Operational wastes	Cargo residues	Animal carcasses	Fishing gear	Ozone depleting substances
J. Container/gas carrier																
K. Container vessel	X	X						X								
L. Container vessel																
M. Roro/Ropax	X	X				X	X	X	X	X						
N. Container/bulk carrier	X	X				X	X	X	X	X	X	X				
O. Container/oiltanker	X	X				X	X	X	X	X						
P. Ferry	X	X				X	X	X	X	X						
Q. Fishing vessel	X		X						X			X				
R. Cargo vessel/oil tanker	X	X								X		X				
S. Car carrier/oil tanker	X	X														
T. Cargo ship	X	X														
U. Container ship	X	X														
V. Passenger vessel	X	X				X	X	X	X	X		X				X
W. Yacht																X
X. Yacht																

Annex C Results online survey

CE Delft-EMSA study on Ship-generated Waste

1. What type of ship-generated waste is applicable in your case? (possible to select more than one)
Answer

Answer	Total	% of answers	%
Oily bilge water	14		82
Oily residues (sludge)	14		82
Oily tank washings	4		24
Sewage	14		82
Plastics	13		76
Food wastes	12		71
Domestic wastes	12		71
Cooking oil	10		59
Incineration ashes	4		24
Operational wastes	7		41
Cargo residues	8		47
Total number of respondents: 17 **Skipped question: 0**		**0% 20% 40% 60% 80%**	

The following questions are about oily bilge water (MARPOL ANNEX I).
The information available to us shows that the waste flow diagram of oily bilge water looks as follows: Oily bilge water is collected in a holding tank and either disposed of directly to a port reception facility or, more often, treated in an oil/water separator. These separators are equipped with outlet valves that open as long as the oil content of 15 ppm or less. The clean water is either discharged to sea or kept in another holding tank. The oil fraction from the oil/water separator is either fed into a waste oil or sludge tank and treated as such, or directly transferred to a port reception facility.

2. In your opinion, does the waste flow diagram contain all relevant routes for the management of oily bilge water?

Answer	Total	% of answers	%
Yes	12		86
No	2		14
I do not know	0		0
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

3. What are other ways to manage oily bilge water in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

4. We assume that the amount of oily bilge water generated per day varies from 0.01 to 13 m^3 and that the quantity cannot be related to either fuel use or distance sailed. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	10		71
No	2		14
I do not know	2		14
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

5. **What are your estimates for the amount of oily bilge water generated per day (please specify and if possible, provide links to documents, websites or other information sources)?**

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

The following questions are about oily residues (sludge) (MARPOL ANNEX I). The information available to us shows that the waste flow diagram of oily residues (sludge) looks as follows: Sludge is generally collected in a sludge tank, a waste fuel tank, a waste oil tank or a lube oil or fuel oil drain tank. It may be transferred directly from the tank to a port reception facility. In other cases, the quantity is reduced in an evaporator which evaporates water from the sludge. It can also be incinerated on-board, in which case the incinerator ashes are delivered to the port reception facility.

6. **In your opinion, does the waste flow diagram contain all relevant routes for the management of oily residues?**

Answer	Total	% of answers	%
Yes	6		43
No	4		29
I do not know	4		29
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

7. **What are other ways to manage oily residues in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?**

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14 **Skipped question: 3**		**0% 20% 40% 60% 80%**	

8. Do you agree that the amount of fuel consumed and the type of fuel are the most important drivers for the amount of sludge generated on-board?

Answer	Total	%
Yes	9	64
No	2	14
I do not know	3	21

Total number of respondents: 14
Skipped question: 3

9. We assume that the amount of oily residues generated per day per tonne of HFO varies from 0.0002 to 0.05 m^3. Do you agree with these numbers?

Answer	Total	%
Yes	4	29
No	5	36
I do not know	5	36

Total number of respondents: 14
Skipped question: 3

10. We assume that the amount of oily residues generated per day per tonne of MGO varies from 0.001 to 0.3 m^3. Do you agree with these numbers?

Answer	Total	%
Yes	4	29
No	6	43
I do not know	4	29

Total number of respondents: 14
Skipped question: 3

11. What are your estimations for the amount of oily residues generated per day and per tonne of fuel (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14 Skipped question: 3		0% 20% 40% 60% 80%	

12. Our information indicates that the amount of sludge that is heated can be reduced up to 60% by using an evaporator. Do you agree with this estimate?

-

Answer	Total	% of answers	%
Yes	3		21
No	1		7
I do not know	10		71
Total number of respondents: 14 Skipped question: 3		0% 20% 40% 60% 80%	

13. If you disagree on the information on sludge reduction from using an evaporator, could you provide some additional information?

Answer	Total	% van Total number of respondents	%
Open Answer	4		24
Total number of respondents: 4 Skipped question: 13		0% 20% 40% 60% 80%	

14. Our information indicates that the amount of sludge can be reduced up to 99% by using an incinerator. Do you agree with this estimate?

Answer	Total	% of answers	%
Yes	5		36
No	1		7
I do not know	8		57
Total number of respondents: 14 Skipped question: 3		0% 20% 40% 60% 80%	

15. If you disagree with the information on sludge reduction from using an incineration, could you provide some additional information?

Answer	Total	% of Total number of respondents	%
Open Answer	3		18
Total number of respondents: 3		**0% 20% 40% 60% 80%**	
Skipped question: 14			

The following questions are about oily tank washings (MARPOL ANNEX I).
The information available to us shows that the waste flow diagram of oily tank washings looks as follows: Oily tank washings are collected in holding tanks. In some cases, the tank holdings are allowed to settle and the water fraction is discharged to sea, while the oily fraction is delivered to a waste reception facility. In other cases, the entire contents of the tank are delivered in port.

16. In your opinion, does the waste flow diagram contain all relevant routes for the management of oily tank washings?

Answer	Total	% of answers	%
Yes	3		75
No	1		25
I do not know	0		0
Total number of respondents: 4		**0% 20% 40% 60% 80%**	
Skipped question: 13			

17. What are other ways to manage oily tank washings in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	4		24
Total number of respondents: 4		**0% 20% 40% 60% 80%**	
Skipped question: 13			

18. We assume that the amount of waste generated per tank washing varies from 1 to 2 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	0		0
No	3		75
I do not know	1		25
Total number of respondents: 4		**0% 20% 40% 60% 80%**	
Skipped question: 13			

19. What are your estimations for the amount of oily tank washings generated per day and per tank washing (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	4		24
Total number of respondents: 4		**0% 20% 40% 60% 80%**	
Skipped question: 13			

The following questions are about sewage (MARPOL ANNEX IV).
The information available to us shows that the waste flow diagram of sewage looks as follows: Most ships have a sewage treatment plant in which the black water is treated. The effluent of the sewage treatment plant is either discharged directly to the sea or kept in a holding tank. Ships that do not have a sewage treatment plant collect the black water in a holding tank. The holding tank is sometimes also used to collect grey water and/or galley water. From the holding tank, it can be either discharged to sea or, in especially sensitive sea areas such as the Baltic, delivered at port reception facilities. The latter is only compulsory for passenger ships.

20. In your opinion, does the waste flow diagram contain all relevant routes for the management of sewage?

Answer	Total	% of answers	%
Yes	8		57
No	4		29
I do not know	2		14
Total number of respondents: 14		**0% 20% 40% 60% 80%**	
Skipped question: 2			

21. What are other ways to manage sewage in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14		**0% 20% 40% 60% 80%**	
Skipped question: 2			

22. We assume that the amount of sewage generated per person per day varies from 0.04 to 0.26 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	6		43
No	2		14
I do not know	6		43
Total number of respondents: 14 Skipped question: 2		0% 20% 40% 60% 80%	

23. What are your estimations for the amount of sewage generated per person per day (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	14		82
Total number of respondents: 14 Skipped question: 2		0% 20% 40% 60% 80%	

The following questions are about plastics (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of plastics looks as follows: Plastics are generated by hoteling and cargo handling. Plastics are collected in bags or bins. Sometimes clean and dirty plastics are collected separately, especially when they are to be delivered to a port reception facility. Dirty plastics are sometimes kept separate and added to the food waste. Plastics are sometimes incinerated when the ship incinerator is certified for this use. However, since not all plastics can be incinerated safely and not all crews have the expertise to separate different types of plastics, ships may choose not to incinerate plastics even when they have an on-board incinerator. Because not all plastics are fit for incineration, the amount of plastic waste is almost never reduced to zero.

24. In your opinion, does the waste flow diagram contain all relevant routes for the management of plastics?

Answer	Total	% of answers	%
Yes	7		54
No	5		38
I do not know	1		8
Total number of respondents: 13 Skipped question: 2		0% 20% 40% 60% 80%	

25. What are other ways to manage plastics in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%

Answer	Total	% van Total number of respondents	%
Open Answer	13		76
Total number of respondents: 13 Skipped question: 2		0% 20% 40% 60% 80%	

26. We assume that the amount of plastics generated per person per day varies from 0.001 to 0.016 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	5		38
No	3		23
I do not know	5		38
Total number of respondents: 13 Skipped question: 2		0% 20% 40% 60% 80%	

27. What are your estimations for the amount of plastics generated per person per day (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	13		76
Total number of respondents: 13 Skipped question: 2		0% 20% 40% 60% 80%	

The following questions are about food wastes (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of food wastes looks as follows: Food waste is generated in the galley and in the mess or restaurant. Sometimes, soft organic wastes and hard organic wastes are collected separately. Soft organic waste is either disposed at sea, or comminuted and disposed at sea, or, when disposal at sea is not allowed or against the company policy, kept in a galley tank or a greywater sewage tank. Hard organic waste and packages are collected in bags and bins and disposed at port reception facilities.

28. In your opinion, does the waste flow diagram contain all relevant routes for the management of food wastes?

Answer	Total	% of answers	%
Yes	4		33
No	6		50
I do not know	2		17
Total number of respondents: 12 Skipped question: 2		0% 20% 40% 60% 80%	

29. What are other ways to manage food waste in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	12		71
Total number of respondents: 12 Skipped question: 2		0% 20% 40% 60% 80%	

30. We assume that the amount of food waste generated per person per day varies from 0.01 to 0.016 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	4		33
No	3		25
I do not know	5		42
Total number of respondents: 12 Skipped question: 2		0% 20% 40% 60% 80%	

31. What are your estimations for the amount of food wastes generated per person per day (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	12		71
Total number of respondents: 12 Skipped question: 2		0% 20% 40% 60% 80%	

The following questions are about domestic wastes (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of domestic wastes looks as follows: After collection, domestic waste is sometimes compacted or crushed and stored in bags or bins. Sometimes, it is directly disposed in a port reception facility, and sometimes it is incinerated on-board and the ashes disposed of in port.

32. In your opinion, does the waste flow diagram contain all relevant routes for the management of domestic wastes?

Answer	Total	% of answers	%
Yes	9		75
No	2		17
I do not know	1		8
Total number of respondents: 12		0% 20% 40% 60% 80%	

Answer	Total	% of answers	%
Skipped question: 1			

33. What are other ways to manage domestic wastes in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	12		71
Total number of respondents: 12		0% 20% 40% 60% 80%	
Skipped question: 1			

34. We assume that the amount of domestic waste generated per person per day varies from 0.001 to 0.02 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	8		67
No	0		0
I do not know	4		33
Total number of respondents: 12		0% 20% 40% 60% 80%	
Skipped question: 1			

35. What are your estimations for the amount of domestic wastes generated per person per day (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	12		71
Total number of respondents: 12		0% 20% 40% 60% 80%	
Skipped question: 1			

The following questions are about cooking oil (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of cooking oil looks as follows: Generally, cooking oil is generated during food preparation, stored into a container and disposed at a port reception facility. On some ships, it used to be customary to mix the cooking oil with sludge and treat it as sludge. While MEPC 68 (May 2015) decided that this was not in line with MARPOL Annex V, it is still customary on some ships (MEPC 68/21 paragraph 12.14).

36. In your opinion, does the waste flow diagram contain all relevant routes for the management of cooking oil?

Answer	Total	% of answers	%
Yes	7		70
No	2		20
I do not know	1		10
Total number of respondents: 10 Skipped question: 3		0% 20% 40% 60% 80%	

37. What are other ways to manage cooking oil in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	10		59
Total number of respondents: 10 Skipped question: 3		0% 20% 40% 60% 80%	

38. We assume that the amount of cooking oil generated per day per person varies from 0.01 to 0.016 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	3		30
No	3		30
I do not know	4		40
Total number of respondents: 10 Skipped question: 3		0% 20% 40% 60% 80%	

39. What are your estimations for the amount of cooking oil generated per person per day (please specify and if possible, provide links to documents, websites or other information sources) ?
(Iedere respondent kon één enkel open Answer van maximum 2000 tekens ingeven.)

Answer	Total	% van Total number of respondents	%
Open Answer	10		59
Total number of respondents: 10 Skipped question: 3		0% 20% 40% 60% 80%	

The following questions are about incineration ashes (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of incineration ashes looks as follows: Ashes are generated in the incinerator, collected in bags and disposed of at a port reception facility.

40. In your opinion, does the waste flow diagram contain all relevant routes for the management of incineration ashes?

Answer	Total	% of answers	%
Yes	3		75
No	0		0
I do not know	1		25
Total number of respondents: 4 Skipped question: 6		0% 20% 40% 60% 80%	

41. What are other ways to manage incineration ashes in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	4		24
Total number of respondents: 4 Skipped question: 6		0% 20% 40% 60% 80%	

42. **We assume that the amount of incineration ashes generated is 1-2% the amount of waste that is incinerated. Do you agree with these numbers?**

Answer	Total	% of answers	%
Yes	1		25
No	1		25
I do not know	2		50
Total number of respondents: 4 **Skipped question: 6**		0% 20% 40% 60% 80%	

43. **What are your estimations for the amount of incineration ashes generated per month (please specify and if possible, provide links to documents, websites or other information sources)?**

Answer	Total	% van Total number of respondents	%
Open Answer	4		24
Total number of respondents: 4 **Skipped question: 6**		0% 20% 40% 60% 80%	

The following questions are about operational wastes (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of operational wastes looks as follows: Operational waste, however defined, is collected and stored. In some cases it is incinerated, in other cases it is disposed of in port reception facilities.

44. **Our information indicates that the definition of operational wastes varies considerably. Which of the following do you consider operational wastes?**

Answer	Total	% of answers	%
Waste generated during cargo handling (pallets, plastic packages, etc.)	0		0
Wastes emanating from the operation of a ship (empty paint cans, worn ropes, etc.)	3		43
Domestic wastes not elsewhere classified (fluorescent tubes, ...)	0		0
All wastes not elsewhere classified.	4		57
Other, please specify	0		0
Total number of respondents: 7 **Skipped question: 3**		0% 20% 40% 60% 80%	

45. In your opinion, does the waste flow diagram contain all relevant routes for the management of operational wastes?

Answer	Total	% of answers	%
Yes	3		43
No	4		57
I do not know	0		0
Total number of respondents: 7 Skipped question: 3		0% 20% 40% 60% 80%	

46. What are other ways to manage operational wastes in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	7		41
Total number of respondents: 7 Skipped question: 3		0% 20% 40% 60% 80%	

47. We assume that the amount of operational wastes generated per person per day varies from 0.001 to 0.1 m^3. Do you agree with these numbers?

Answer	Total	% of answers	%
Yes	4		57
No	1		14
I do not know	2		29
Total number of respondents: 7 Skipped question: 3		0% 20% 40% 60% 80%	

48. What are your estimations for the amount of operational wastes generated per person per day (please specify and if possible, provide links to documents, websites or other information sources) ?

Answer	Total	% van Total number of respondents	%
Open Answer	7		41
Total number of respondents: 7 Skipped question: 3		0% 20% 40% 60% 80%	

The following questions are about cargo residues (MARPOL ANNEX V).
The information available to us shows that the waste flow diagram of cargo residues looks as follows: Sometimes the cargo holds are rinsed with seawater and the residues disposed of at sea. Sometimes the cargo residues are collected in bags and either handled by the stevedores or disposed of in the port reception facility.

49. In your opinion, does the waste flow diagram contain all relevant routes for the management of cargo residues?

Answer	Total	% of answers	%
Yes	6		75
No	2		25
I do not know	0		0
Total number of respondents: 8 **Skipped question: 0**		**0% 20% 40% 60% 80%**	

50. What are other ways to manage cargo residues in your opinion (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	8		47
Total number of respondents: 8 **Skipped question: 0**		**0% 20% 40% 60% 80%**	

51. We assume that the amount of cargo residues generated per discharge of cargo is a maximum of 1% of the cargo load. Do you agree with this number?

Answer	Total	% of answers	%
Yes	2		25
No	4		50
I do not know	2		25
Total number of respondents: 8 **Skipped question: 0**		**0% 20% 40% 60% 80%**	

52. What are your estimations for the amount of cargo residues generated per cargo discharge (please specify and if possible, provide links to documents, websites or other information sources)?

Answer	Total	% van Total number of respondents	%
Open Answer	8		47
Total number of respondents: 8		0% 20% 40% 60% 80%	
Skipped question: 0			