NATO INTERNATIONAL STAFF - DEFENCE SUPPORT DIVISION

ALLIED MARITIME ENVIRONMENTAL PROTECTION PUBLICATION

AMEPP-4
Edition 2

ALLIED NAVAL ENGINEERING PUBLICATION

ANEP-59

GUIDANCE FOR THE INTEGRATION OF MARITIME ENVIRONMENTAL PROTECTION (MEP) FUNCTIONAL REQUIREMENTS INTO A SHIP DESIGN

JANUARY 1999

I

AMEPP 4
Edition 2

ANEP 59

GUIDANCE FOR THE INTEGRATION OF MARITIME ENVIRONMENTAL PROTECTION (MEP) FUNCTIONAL REQUIREMENTS INTO A SHIP DESIGN

This AMEPP/ANEP was developed jointly by AC/141(SWG/12) on Maritime Environmental Protection and AC/141(NG/6) on Ship Design. As an AMEPP, it is one of a series developed and promulgated by SWG/12 on various maritime environmental protection matters. As an ANEP, it is one of a series of publications developed and promulgated by NG/6 on various naval ship design matters.

JANUARY 1999

I

NORTH ATLANTIC TREATY ORGANIZATION

MILITARY AGENCY FOR STANDARDIZATION

NATO LETTER OF PROMULGATION

January 1999

1. AMEPP 4/ANEP 59 - GUIDANCE FOR THE INTEGRATION OF MARITIME ENVIRONMENTAL PROTECTION (MEP) FUNCTIONAL REQUIREMENTS INTO SHIP DESIGN - is a NATO UNCLASSIFIED publication.

2. AMEPP 4/ANEP 59 is effective NATO-wide upon receipt. As Edition 2 of AMEPP 4, this document replaces AMEPP 4 Edition 1, dated August 1995, which can be destroyed in accordance with NATO and National regulations.

3. AMEPP 4/ANEP 59 contains only factual information. Changes to this publication are not subject to ratification procedures and will be promulgated as necessary by AC/141(SWG/12) and AC/141(NG/6).

4. AMEPP 4/ANEP 59 is releasable to Partnership for Peace nations, and distribution of this publication to equipment contractors and suppliers is both permitted and encouraged.

A. GRØNHEIM
Major-General, NOAF
Chairman

RECORD OF CHANGES

CHANGE DATE	DATE ENTERED	EFFECTIVE DATE	BY WHOM ENTERED
MAY 2003	MAY 2003	MAY 2003	[signature]

ALLIED MARITIME ENVIRONMENTAL PROTECTION PUBLICATION

AMEPP-4

Edition 2

ALLIED NAVAL ENGINEERING PUBLICATION

ANEP-59

GUIDANCE FOR THE INTEGRATION OF MARITIME ENVIRONMENTAL PROTECTION (MEP) FUNCTIONAL REQUIREMENTS INTO A SHIP DESIGN

JANUARY 1999

1 CONTENT AND OBJECTIVES

The purpose of this document is to provide general guidance to naval architects and marine system designers for integrating environmental compliance requirements into new ship designs with minimal adverse impacts on operational capabilities, readiness, safety, survivability and crew's quality of life.

This document contains only the management policies, shipboard treatment possibilities, and some recommendations for different technologies. The functional requirements of treatment equipment are not described. In particular, this guidance contains the following aspects :

- introduction and application of environmental regulations,
- operational requirements considerations,
- shipboard MEP management strategies,
- design constraints and integration aspects.
- recommendations for waste management practices.

Some indications are given for optional MEP-equipment for possible waste treatment on board existing or new ships. Reference to optional scenarios and technologies presented in the NIAG report D(96)1 or in this document must be considered as a first non exhaustive list of examples.

The present AMEPP, which is mentionned in ANEP-24, is part of the AMEPP series on MEP which include the following complementary documents :

- AMEPP 1 : NATO navies pollution abatement policies,
- AMEPP 2 : National navy regulation for the disposal of waste,
- AMEPP 3 : Shipboard pollution abatement equipment catalogue,
- AMEPP 4 : The present AMEPP in replacement of the « ship design guidance »,
- AMEPP 5 : Ozone depleting substitute solvent and cleaning agent alternatives,
- AMEPP 6 : Hazardous materials offload guide,
- AMEPP 7 : Glossary of terms and definitions in the AMEPP series.

Some non exhaustive data relative to possible scenarios and technologies are also presented in the NIAG report D(96)1 about a « prefeasibility study on a NATO environmentally sound ship of the 21st century ».
Other documents as STANAG 4167 are directly linked to this AMEPP 4.

Considering their national policy, strategy, and abatement programmes, each country is encouraged to use this AMEPP in their own ship design in order to provide a common basis for the introduction of equipment and procedures to enhance standardization and interoperability, but remains free to choose the different options, scenarios and technologies proposed in this document.

2 GENERALITIES

2.1 INTRODUCTION AND CHALLENGE

Executing their operational tasks NATO Navy ships generate wastes. Ships have to comply with a wide and complex range of international and national environmental laws, regulations and policies around the world.

The most important maritime environmental regulations are specified in the MARPOL Convention which prohibits, under certain conditions, the discharge of specific wastes directly into the sea. As a consequence, storage capacity and/or process equipment on board ships is required. The choice of the best option depends on the operational duration time, the type of ship, the crew size and the operation area ("Special areas").

Current waste management policies and treatment technologies are implemented in order to :

- ensure compliance with a number of international and national regulations.
- ensure the safety and health of the crew,
- maintain an acceptable standard of habitability,
- minimize the volume of wastes to be stored on board ships and to minimize the frequency of visits to ports for off-loading such wastes, also contributing to "force protection".

The term "habitability" is an important factor to apply to this document, because habitability describes all the factors which collectively constitute the environment in which the ship's crew is required to live and work efficiently.

Elevating the importance of environmental compliance will also minimize the space and weight allocations that must be reserved for pollution control and pollution prevention systems, especially if they would otherwise have to be retrofitted at a later time.

2.2 APPLICATION AREA

This document first addresses to new ships and under certain conditions considers the retrofit applications, as far as possible.

They are three main representative categories of ships that may be identified as a result of the assessment of typical operational profiles and crew sizes :

- small ships : mine warfare vessels, ocean patrol vessels, corvettes and their supporting vessels,
- medium ships : frigates and destroyers,
- large ships : aircraft carriers, amphibious transport ship and supply/support ships.

Submarines are presently excluded because of their particular design aspects and national classification issues. But many of the design features presented here for surface vessels may be applicable to submarines under certain conditions.

2.3 WASTE STREAM CHARACTERIZATION

Shipboard waste streams include, but are not limited to, liquid waste (oily water, black water, grey water), solid waste (food waste, garbage such as : plastic, metal, glass, paper, cardboard), medical (including female waste; see annex A), used or excess hazardous material and air emissions.

Emissions to the surface water also include anti-foulant hull paint leachates, cooling water and effluent from desalination equipment.

Gaseous emissions are a special category : because of their properties they cannot be easily identified and considered in the same way as liquid or solid wastes.

In annex A, an enumeration of the MARPOL-harmful substances, which are generated on board navy ships, has been projected schematically.

Nuclear waste is specifically excluded from this AMEPP.

2.4 DEFINITIONS

The definitions of these different waste streams are provided by AMEPP 7 "Glossery of Terms and definitions in the AMEPP series".

2.5 WASTE MANAGEMENT AND DISPOSAL DECISION SCHEME

The value analysis methodology have also to be applied during the system design process to compare and evaluate different integrated systems to comply with the chosen strategy (environmental regulations, operational requirements, waste management policy, functional requirements for each waste).

3 ENVIRONMENTAL REGULATIONS

3.1 INTERNATIONAL AND NATIONAL REGULATIONS

The most important maritime environmental regulations are prescribed in the MARPOL 73/78 convention which regulate the discharges/emissions of the following waste streams : solid waste, liquid waste, hazardous materials and air emissions. These rules, which have to be known prior to the start of a design, currently consists of 6 annexes :

- Annex 1 : Prevention of pollution by oil,
- Annex 2 : Control of pollution by noxious liquid substances in bulk,
- Annex 3 : Prevention of pollution by harmful substances in packaged form,
- Annex 4 : Prevention of pollution by sewage,
- Annex 5 : Prevention of pollution by garbage,
- Annex 6 : Prevention of pollution by air emissions from ships.

The MARPOL (IMO) discharge criteria of the different waste streams are enumerated in respective tables 3A, 3B and 3C.

TABLE 3A : SOLID WASTE

Type	*Outside special areas*	*In special areas*
Plastics-(including synthetic ropes and fishing nets)	Discharge prohibited	Discharge prohibited
Floating dunnage, lining and packing materials	> 25 miles offshore	Discharge prohibited
Paper, rags, glass, metal, bottles, crockery and simular waste	> 12 miles	Discharge prohibited
All other garbage including paper, rags, glass, etc. comminuted or ground	> 3 miles	Discharge prohibited
Food waste	> 12 miles	> 12 miles
Food waste comminuted or ground	> 3 miles	> 12 miles
Mixed waste types	The more stringent discharge requirements	The more stringent discharge requirements
Maintenance waste	Discharge prohibited	Discharge prohibited
Medical waste	Discharge prohibited	Discharge prohibited

TABLE 3B : LIQUID WASTE

Type	*Area*
Sewage	< 4 nm, no discharge 4 - 12 nm, or certain areas, discharge is allowed after comminute, disinfection > 12 nm, discharge is allowed
Grey water	Discharge is allowed except in specific areas
Oily water	< 15 ppm oil, discharge allowed; in ports and inland waters, no discharge
Ballast water	Discharge allowed if < 15 ppm oil

There is a growing need to treat oily water to an increasingly high standard prior to discharge. In addition, currently, there are non MARPOL 73/78 regulations that prohibits the discharge of grey water. But grey water is becoming increasingly difficult to discharge in National waters and port areas, and in many locations Navies are incurring a severe cost penalty for shore-based disposal.

TABLE 3C : AIR EMISSIONS

Requirements for control of air pollution	***MARPOL ANNEX 6 Regulation***
Ozone depleting substances (ODS) Deliberate emissions of ozonedepleting substances shall be prohibited. New installations which contain ozone depleting substances shall be prohibited	
Nitrogen Oxides (NOx): 17.0 g/kWh when n is less than 130 rpm; $45.0*n^{(-0,2)}$ g/kWh when n is 130 or more but less than 2000 rpm; 9.8 g/kWh when n is 2000 rpm or more When n= rated engine speed (crankshaft revolutions per minute	
Sulphur Oxides (SOx) : The sulphur content of any fuel oil used on board ships shall not exceed 4.5% m/m The sulphur content of fuel oil used on board ships in a SOx Emission Control Area does not exceed 1.5% m/m	
Volatile organic compounds (VOC) Volatile organic compounds (VOCs) from tankers are to be regulated in ports or terminals under the jurisdiction of a Party to the Protocol of 1997	

More, most countries throughout the world have their own set of environmental laws which regulate all environmental discharge, including those from ships and are often more restrictive than those issued from international regulations (examples : clear air act, clean water act, decrees, European Community rules, ...).

3.2 NATO NAVIES POLICIES

For the disposal of waste, many national navies may adopt other specific regulations to design the shipboard MEP systems.

These policies are given in the AMEPP's 1 and 2, but may also be the result of common policies, jointly adopted in case of cooperation between several national navies.

4 OPERATIONAL REQUIREMENTS

4.1 WASTE GENERATION RATES IN NATO NAVIES

The mass and volume of waste generated on NATO navy ships were determined, generally as a function of the particular navy, crew size, ship type and mission profile.

Grey water generation dominates liquid wastes, generating several times more in volume than sewage. Sewage volume varies significantly, depending upon whether the ship collection system is gravity or vacuum (vacuum systems, and their lack of need for flushing water, only use one 1/6 volume of a conventional gravity collection system).

With the exception of oily waste and some hazardous substances, all other on board generated waste is a function of crew size :

- Oily waste is a function of the type of propulsion plant, the general state of repair of the machinery in the main and auxiliary machinery spaces and the maintenance philosophy.
- Hazardous materials encompasses a wide variety of substances used on a ship for cleaning, maintenance, lubricating and other applications. The major hazardous material waste streams are the following : paint and paint debris, oily rags, spent solvents, used petroleum and synthetic oils, mercuric chloride wastewater, used filters, empty aerosol cans and gas cylinders.

Table 4A identifies NATO average waste generation rates that may be used when selecting and sizing shipboard waste processing equipment.

TABLE 4A : WASTE GENERATION RATES

WASTE STREAM	RATE / PERSON (NATO average)	
LIQUID WASTE	**kg/day**	**liter/day**
Oily water		4000 (medium size ship)
Sewage		40 (gravity) 10-15 (vacuum)
Grey water		120
SOLID WASTE	**kg/day**	**liter/day**
Food	0,665	1,6
Plastic	0,1	2,9
Paper/cardboard	0,45	2,1
Metal	0,127	1,1
Glass	0,15	1,3
Medical waste	0,009	0,2
Hazardous substances	0,024	0,9

Obviously, these rates vary from one country to another and each national navy can use its own waste generation rates knowed by their own experience feedback.

4.2 NATO SHIPS REFERENCE MISSION PROFILE AND DURATION

The knowledge of the reference mission duration is very important for the choice of a strategy and the design of shipboard environmental systems (for example, the calculation of holding capacities and its coherence with the required autonomy).

This figure is linked to the category of ship as described in §.2.3 and the mission profile. No any value can be given in this AMEPP. It is necessary to refere to the program staff target which may be national or multilateral in case of cooperation.

4.3 NATO SHIPS COMPLEMENT

The dominant theme is a gradual decrease in the number of ships's personnel aboard each vessel. NATO navies are learning to "do more with less" as a trend in automation and efficiency requires fewer sailors. It is estimated that the total shipboard personnel will decrease by 10 % by 2005 and so will ship's generated waste.

The only exceptions are oily wastes and engine exhaust gases, which correlate with the type of ship.

5 WASTE MANAGEMENT STRATEGIES

5.1 GENERAL CONSIDERATIONS

In annex B 2 a decision scheme is projected how to manage the different waste streams on board to comply with maritime environmental protection law and legislation.

This flow diagram describes boxes that have to be filled with technology and has to be used to investigate the interfaces between the boxes and the interfaces « ship to shore » for handing over the waste to tenders or port reception facilities.

Once the requirements, both environmental and operational, were defined specific waste management options for addressing that waste can be developed and reviewed. The following general guidelines should be used in developing a strategy to deal with different waste streams :

- waste streams which are permitted to be discharged into the sea in accordance with MARPOL regulations are not to be mixed with waste streams which are not permitted to be discharged,
- different waste streams, each of which are permitted to be discharged into the sea in accordance to MARPOL regulations, can be mixed,
- waste streams which are not permitted to be discharged into the sea in accordance to MARPOL regulations, must be retained on board until they can be disposed of in port, and must not to be mixed.

Starting from these assumptions, the waste management strategies can follow general international environmental management practice presented in the following table 5E :

TABLE 5A : SCENARIOS

Order of priority	SCENARIOS FOR WASTE MANAGEMENT/ GENERATION
1	Source reduction (example : substitution of products or source elimination)
2	Minimization (examples : volume reduction at source, changing a process)
3	Shipboard reuse/recovery
4	Shipboard treatment (elimination ; example destruction)
5	Collection, hold, transfert to a supplier or a port facility for subsequent treament shore-based for reuse or elimination
6	Collection, hold, discharge at sea when legaly allowed

All these options have to include the waste taken either separately or with other wastes (under a possible integrated treatment for future strategies).

It is also important to note that there are a variety of commercially available, off-the-shelf, pollution abatement systems which can greatly assist ships in complying with MARPOL regulations. As such there should be no need to specially develop MEP equipment to process shipboard waste.

5.2 PERSPECTIVES FOR NATO NAVIES STRATEGIES

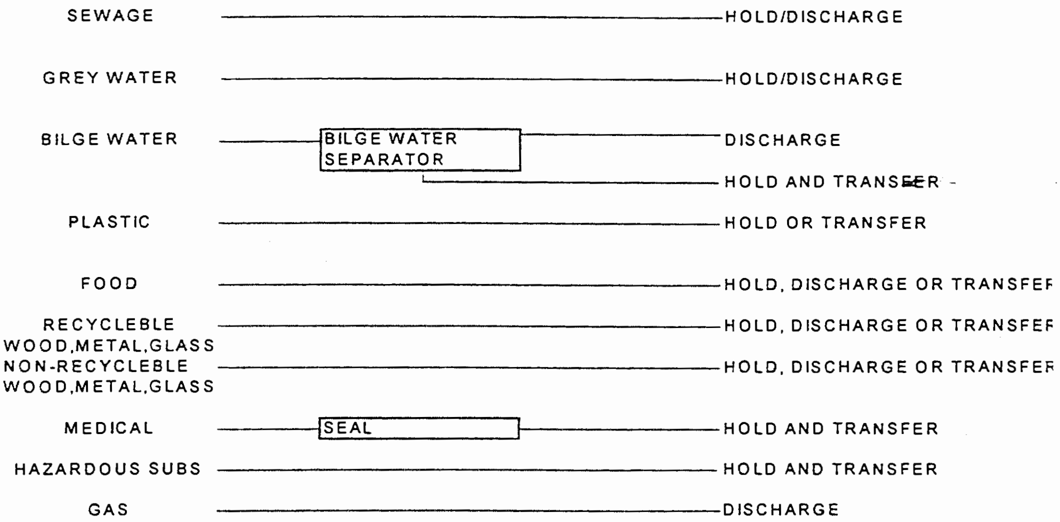
For the NATO navies, the challenge essentially consists in making the right choice between the storage and the treatment strategies, by using the disposal decision scheme presented in §.2.5 and jointed in annex B.

Different levels of strategies can be considered, starting from a "minimum option", which may be essentially directed towards a shipboard temporary storage strategy, up to « near future technologies options » which may proposed optimized solutions to concentrate the waste or architectures to destroy the waste with integrated systems.

A) Minimum option (figure 5A)

The strategy discussed under this heading is to hold all unprocessed waste by making use of tanks and all solid waste on board the ship with storage rooms, with the intention of discharging it to port facilities or at sea, in allowed zones

FIGURE 5A : MINIMUM OPTION

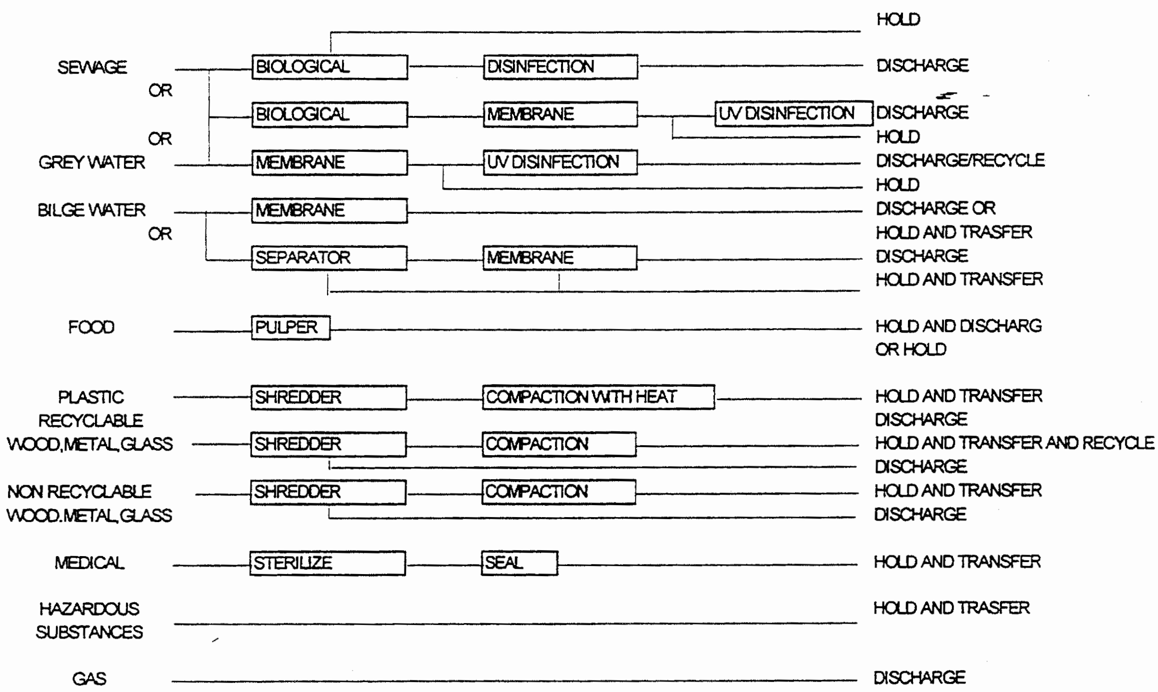


On these assumptions, all wastes generated are collected, and held, with the exception of oily waste water which have to be treated. Sewage, grey water, and food waste are discharged when discharge is allowed. The other waste streams may be transferred to tenders or disposed of to port reception facilities.

B) **Intermediate option (figure 5B)**

The previous strategy does not offer a maximum environmental protection of the seas (the duration of the autonomy duration remains short, necessity to find optimized ways in term of space, compliance with specific national regulations). So, it may be necessary to optimize the shipboard waste management systems.

FIGURE 5B : INTERMEDIATE OPTION



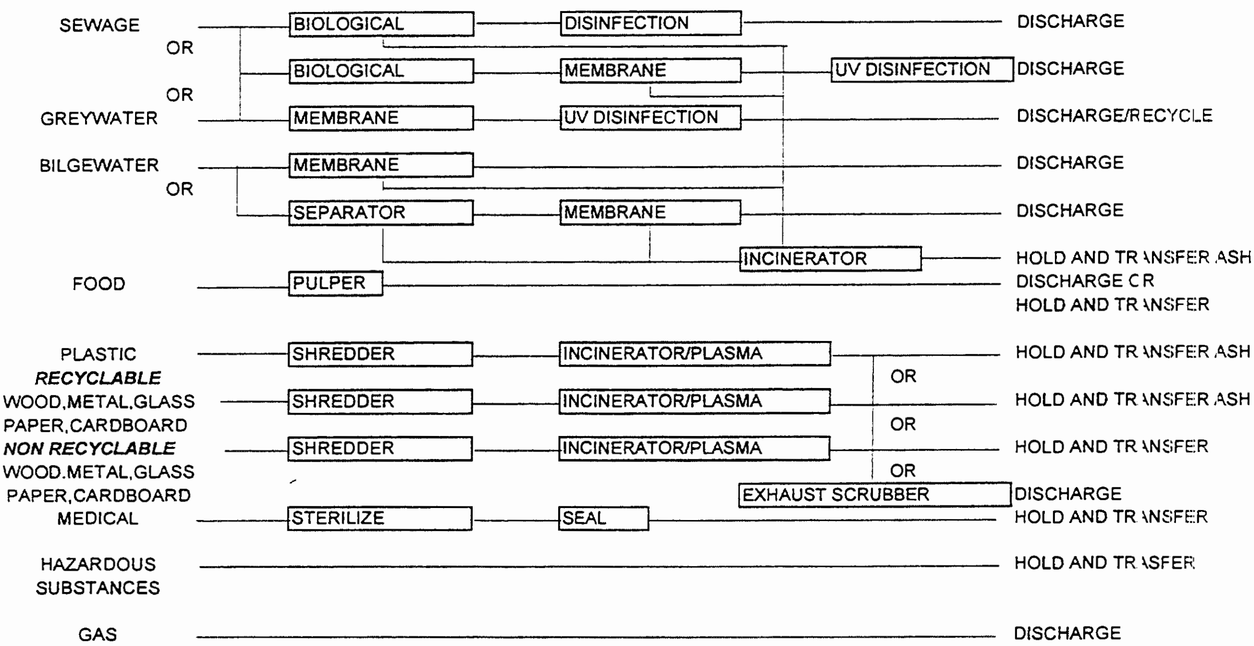
The use of more adapted technologies minimizing the volume of waste collected on board and treating separately each waste must be choosen, such as the compaction of plastics that cannot be discharged at sea, or the filtering by specific devices of sewage and grey water which require high capacity volumes.

The secondary waste streams (sludge, solid waste compacted, ...) have to be stored on board and then transferred to tenders or disposed of to port reception facilities.

C) Maximum option (figure 5C)

In this option, to increase much more the autonomy, it may be possible to require some integrated systems which would able to treat simultaneously different kind of waste with adapted devices, up to the elimination on board of these waste.

FIGURE 5C : MAXIMUM OPTION



Reducing the volumes of black, grey and oily water may lead to a change in their compositions and thus, influence the performance of installed treatment systems.

The selection of new treatment processes will require consideration of both the volume and composition of the wastewater generated following any minimization initiatives, particularly if a combination of wastewater will be treated.

Some additional efforts have to be added to minimize at source the production of waste : the reduction of the size of crews in NATO ships and the use of more efficient packaging also offer some additive solid waste reduction ways.

Gaseous emissions will decrease continuously, primarily through the implementation of cleaner engines (or better fuels), rather than applying after-emission treatment technology.

6 FUNCTIONAL REQUIREMENTS FOR WASTE MANAGEMENT SYSTEMS

6.1 GENERAL CONSIDERATIONS

For the different wastestreams it is likely that NATO Navies will choose a combination of source reduction, reuse, recycling and degradability, from the three categories of strategies described en §.5.2.

Waste will then be disposed of after using multiple storage/treatment technologies. All of these methods will require some level of waste separation, treatment, storage and disposal or elimination (see waste management figures in annexes C and D).

There are many variations in collection and treatment systems. Navies will have to decide which system will meet their needs the best for a particular ship with its particular mission, crew size and operational duration time.

For each kind of waste, some recommendations may be proposed from the waste source reduction or elimination, its minimization, segregation and collection at source, up to its shipboard storage and/or treatment and its discharge outside the ship for its elimination.

6.2 OILY WATER

A) SOURCE REDUCTION OR ELIMINATION

The contaminants present in oily water (essentially bilge water) are correlated with the type of ship and the type of propulsion systems adopted. They are derived from machine shops, engine rooms and machine/equipment areas.

Several substances (cleaning agents, detergents) act as emulsifiers for oily water mixtures and as such are contaminants of bilge water.

For such substances, the best solution would be to minimize their diversity and to reduce their use in order to simplify the design of shipboard MEP systems for oily water.

B) MINIMIZATION AT SOURCE

It is likely that the volume of oily water to be stored may be reduced if measures are taken to limit contaminants entering the bilge. The possible ways of reducing oily contamination in the bilge area are:

- improved seal technology,
- correct selection of flange or coupling connections,
- proper tightening of screw, bolts, nuts, etc ...,
- early detection and rectification of leaks,
- selective collection of waste oils at source,
- good housekeeping and education to prevent use of the bilge as a dustin.

It may also be possible to reduce the volume of oily water if the requirement for cleaning of decks, engines, equipment, etc..., was reduced (Dry-Bilge System).

C) SEGREGATION AT SOURCE AND COLLECTION

The collection of waste oils at their source and subsequent segregation remove a proportion of the contaminants which are likely to be found in the bilge :

- oily residues resulting from purification of fuels and lubricating oils and bilge water separators, will be collected in a specific tank.

- waste oil from propulsion engines, gear boxes and the auxiliary machines will be collected in a separate tank.

Segregation in the original containers or in small specifically identified tanks may enable shipboard treatment and re-use on board or transfer to a shore-based facility for disposal or treatment.

D) SHIPBOARD FILTERING TREATMENT AND/OR STORAGE

Although the level of contamination may be significantly reduced, it is unlikely that oily contamination would ever be reduced to zero and some typical oily waste management devices as shown in figure 6A (See annex C) may be necessary.

The bilge water has to be removed from all machinery space bilges and pumped into a bilge water holding tank. This oily mixture has to be treated by passing it through a bilge water separator, such as those listed in §.8.2.

The effluent of the separator has to be controlled by an oil content monitor according to IMO Resolution MEPC 60(33) and either discharged into the sea or returned to the bilge water holding tank.

The separated oil has to be collected in a sludge tank and will be disposed of to port reception facilities.

It is important to note that storage of waste oil under anaerobic conditions can introduce the danger of generated hydrogen sulphide gas which is a hazardous and corrosive gas.

E) ELIMINATION AND DISCHARGE

All tanks (containing unprocessed oily water or oily residus and sludge issued from a shipboard treatment) have to be equipped with pipes fitted with flanges referenced IMO/STANAG 4167 for disposal to port reception facilities.

6.3 BLACK WATER

A) SOURCE REDUCTION OR ELIMINATION

The requirement to produce freshwater on board a ship is directly related to the consumption of water and thus, the volume of black water generated.

It is very difficult to act on this field because of the specific human methabolism. The reduction of the size of crews in NATO ships may give some opportunities.

B) MINIMIZATION AT SOURCE

A few measures can be introduced to reduce significantly water consumptions and the shipboard required volume, particularly if holding tanks are used prior to discharge of untreated sewage.

The use of such adapted devices has two benefits :

- a reduction in the volume of freshwater which is need to be produced,
- a reduction in the volumes of wastewater requiring treatment and/or disposal.

The change from gravity flush toilets to a vacuum collection system significantly reduces the volumes of sewage generated (water use reduces from 10-12 litres to 1.5 litres per flush).

Changes to the flushing cycles for urinals may also offer possibilities for water saving (consider regular cleaning and odour prevention).

C) SEGREGATION AT SOURCE AND COLLECTION

Because of some regulation differences about non oily waste water, it is necessary, in a first stage, to distinguish the black water from the grey water and to adopt a segregation at source and a selective collection.

It is important to note that vacuum collected black water is a highly concentrated waste. In a second stage, it is likely to require dilution prior treatment, particularly if conventional shipboard treatment devices are used. It may be possible to use grey water to effect this dilution.

D) SHIPBOARD TREAMENT AND/OR STORAGE

Small ships with a short endurance time at sea do not have enough space for installing a black water treatment plant and the amount of sewage is not sufficient for proper functioning of this treatment plant.

So these ships have to be equipped with a holding tank for black water for discharge into the sea or disposal to port facilities. It is also important to note that storage of the sewage under anaerobic conditions can introduce the danger of generated hydrogen sulphide gas, which is a hazardous and corrosive gas.

For the other ships, the treatment of black water must be possible, eventually with a combined wastewater stream, particularly if there is limited dilution of vacuum collected black water.

These options may require the use of conventional or advanced shipboard treatment plants, such as those listed in §.8.3.

E) ELIMINATION AND DISCHARGE

All tanks (containing unprocessed black water or black water residus and sludge issued from a shipboard treatment) have be equipped with pipes fitted with flanges referenced IMO/STANAG 4167 for disposal to port reception facilities.

6.4 GREY WATER

A) SOURCE REDUCTION OR ELIMINATION

The requirement to produce freshwater on board a ship is directly related to the consumption of water and thus, the volume of grey water generated, without forgetting the water issued from condensation.

It is very difficult to act on this field because of the level of comfort required onboard for the crew. However, the reduction of the size of crews in NATO ships may give some opportunities.

B) MINIMIZATION AT SOURCE

There are a number of changes which can be made on board Navy ships in order to reduce significantly the volume of grey water which is generated.

These options are the following ones :

- installation of water control devices,
- recycling of grey water within individual pieces of equipment (laundry machines),
- treatment of grey water to recover the original quality and for potential re-use for operations where lower grade water is acceptable.

The installation of specific devices to limit the amount of water delivered for use will reduce the amount of fresh water used and thus, the quantity of grey water produced. Such devices which could be installed in washrooms and galley are:

- low flow taps,
- self-closing time delayed showers and taps,
- taps operated by infrared sensors.

Low-water usage laundry machines are also available which use considerably less water than conventionally designed machines. Increased use of dry-cleaning for clothing, uniforms and bedding would also reduce the volume of grey water generated by the laundry.

C) SEGREGATION AT SOURCE AND COLLECTION

Because of some regulation differences about non oily waste water, it is necessary, in a first stage, to distinguish the grey water from the sewage and to adopt a segregation at source and a selective collection.

It is important to note that grey water can be used to effect a dilution with vacuum collected sewage, particularly if conventional shipboard treatment plants are used.

D) SHIPBOARD TREAMENT AND/OR STORAGE

For small ships with a short endurance time at sea, it is not always easy to find enough space for installing a grey water treatment plant. As far as possible, these ships have to be equipped with a holding tank for grey water and other drains for discharge into the sea (where permitted) or disposal to port facilities.

For medium and big size ships, the treatment of grey water may be necessary, eventually with a combined wastewater stream, particularly if there is limited dilution of vacuum collected black water.

This option may require the use of conventional or advanced shipboard treatment plants, such as those listed in §.8.4.

E) ELIMINATION AND DISCHARGE

Currently, there are non MARPOL 73/78 regulations that prohibits the discharge of grey water. So, in most of the cases, grey water and other drains can be discharged directly overboard.

But grey water is becoming increasingly difficult to discharge in National waters and port areas, and in many locations Navies are incurring a severe cost penalty for shore-based disposal.

So, to take into account these local regulations, all tanks (containing unprocessed grey water or grey water residus and sludge issued from a shipboard treatment) have to be equipped with pipes fitted with flanges referenced IMO/STANAG 4167 for disposal to port reception facilities.

6.5 FOOD WASTE

A) SOURCE REDUCTION OR ELIMINATION

It is very difficult to act on this field because of the level of comfort required onboard for the crew and because of the traditional way of life. However, the reduction of the size of crew in NATO ships may give some opportunities.

B) **MINIMIZATION AT SOURCE**

A few measures can be introduced to reduce the food waste generated on board by adopting optimized management methods for the provisions and the preparation of meals.

C) **SEGREGATION AT SOURCE AND COLLECTION**

Because of some regulation differences about liquid/solid waste, it is necessary, in a first stage, to distinguish the food waste from the solid wastes and to adopt a segregation at source and a selective collection.

D) **SHIPBOARD TREAMENT AND/OR STORAGE**

Several strategies may be planned for the shipboard food waste food treatment, before its discharge into the sea or its disposal to port reception facilities.

These treatment options may require the use of conventional or advanced shipboard treatment devices, such as those listed in §.8.5.

E) **ELIMINATION AND DISCHARGE**

According to the treatment device adopted on board, the food waste can be discharged directly overboard after been ground or not, or discharged (after a treatment/storage option) by a pipe fitted with a standardized flange and disposed of to port reception facilities.

6.6 SOLID WASTE

A) **SOURCE REDUCTION OR ELIMINATION**

Waste reduction, and recycling plans on board ships can be adopted using a phased, compartment by compartment approach. Each compartment has different materials to collect and different needs to be addressed in their collection, storage and training.

For solid waste, it is anticipated in near future that metal waste may decrease as metal containers are substituted for current plastic ones, and that new types of biodegradable materials (starch, lactide-based) will be used for food packaging.

Many materials are recyclable or must be disposed of. The following materials are typical in a food service space of a ship :

TABLE 6A : OPTIONS FOR SOLID WASTE MINIMIZATION

Waste Description	***Reduction methods***
Steel and aluminium cans	Juice and soda from bulk dispensers, reusable mugs and glasses, limit use
Clear glass	Purchase product in larger-size containers, seek alternative secondary use for jars or alternative packaging
Plastics (PET, HDPE, PP, PS)	Purchase in larger containers, biodegradables , vacuum pack, alternative packaging
Food waste/grease	Pre-cooked meals, careful procurement, serving size and selection upon request.
Stretch wrap	
Aerosol cans	Alternative packaging
White paper	Double-sided copying, e-mail, minimize printing
Batteries	Use rechargeable batteries

Cardboard	Eliminate secondary packaging, purchase items in larger quantities, take back or reusable packaging
Newspapers/magazines	Sharing/circulating, limiting number distributed, dropping sections

On the other hand, shipboard fresh water production devices have to be improved in order to minimize the consumptions of plastic or glass water bottles. Changing from plastic packaging to paper or carboard can be an other strategy of simplifying waste management on warships.

B) MINIMIZATION AT SOURCE

Some working areas have to be created in order to practise the minimization at source of all the potential solid wastes, especially during the loading operations, at sea from support ships or at berth from the port reception facilities.

C) SEGREGATION AT SOURCE AND COLLECTION

Because of some regulation differences within the categories of solid waste, it is necessary to collect them at source, space by space, in specific boxes or containers, clearly identified (colour, marking, form). They will be separated into the following categories:

- plastics;
- paper/cardboard;
- metal;
- glass;
- trash.

D) SHIPBOARD TREAMENT AND/OR STORAGE

The selected waste have to be transported to a specific area consisting of :

- a waste treatment center (if necessary), where several treatment facilities, such as those described in §.8.6, may be installed according to the port reception facilities constraints.
- a storage room, next to the waste treatment center (when existing), for the storage of solid waste, unprocessed and/or processed. This room may be divided into two parts : a pre-treatment area and a post-treatment area.

For the access of this room, the principle of « non crossing waste and food » must be respected. The waste treatment center and the storage room have to be designed to reduce or to avoid the biological hazards as a result of bacteria, moulds, yeasts and fungi activities.

E) ELIMINATION AND DISCHARGE

Containers have to be used to transport the waste ashore. Transport routes and openings will be installed to transport the waste from the treatment center and the storage room to port reception facilities.

6.7 MEDICAL WASTE

A) SOURCE REDUCTION OR ELIMINATION

It is very difficult to act on this field, especially for large specific ships. However, the reduction of the size of crews in NATO ships may give some opportunities.

B) MINIMIZATION AT SOURCE

For medical waste generated in shipboard hospitals, it will be difficult in future to reduce their rate, because the present and future trends are to use more and more « one use » medical tools in order to comply with hygiene rules.

C) SEGREGATION AT SOURCE AND COLLECTION

Essentially because of the toxic hazard, this kind of waste has not to be mixed with the solid wastes listed in §.6.6.

D) SHIPBOARD TREAMENT AND/OR STORAGE

Medical waste have to be stored in the direct vicinity of the source, that means in the sick bay or ships hospital.

Eventually, according the kind of storage procedures, shipboard treatment facilities, such as those indicated in §.8.7, may be necessary to avoid the biological hazards as a result of bacteria.

E) ELIMINATION AND DISCHARGE

Containers have to be used to transport the waste ashore. Transport routes and openings will be installed to transport the waste from the treatment center and/or the storage room to port reception facilities.

6.8 HAZARDOUS SUBSTANCES

A) SOURCE REDUCTION OR ELIMINATION

For hazardous substances, it is anticipated in near future that the volume of solid-phase hazardous waste may decrease as new materials are substituted.

B) MINIMIZATION AT SOURCE

A few measures can be introduced to reduce the size of cans containing liquid hazardous substances (paints, solvents, ...) in order to avoid the degradation of non used products and their classification as waste.

C) SEGREGATION AT SOURCE AND COLLECTION

Essentially because of the toxic hazard, this kind of waste has not to be mixed with the solid wastes listed in §.6.6.

D) SHIPBOARD TREAMENT AND/OR STORAGE

Chemical and hazardous waste have not to be treated or mixed because of the toxic hazard and the fact, that suppliers do not allow treatment of chemical waste.

These waste will be stored in a special storage room :

- Waste with special recycling procedures, such as batteries or neon light tubes will be stored together with the unused products.
- The storage room for the hazardous waste has to be integrated into the ventilation system (NBC-Defence). The used air has to be discharged directly from the ship.

- This type of waste becomes a problem in case of fire. So a fire-fighting system has to be installed and special procedures when starting a firefighting party will have to be used.

E) ELIMINATION AND DISCHARGE

Containers have to be used to transport the waste ashore. Transport routes and openings will be installed to transport the waste from the storage rooms to port reception facilities.

6.9 GASEOUS EMISSIONS

A) SOURCE REDUCTION OR ELIMINATION

This category of waste deals with the gas issued from the propulsion system, the chemical products used in air conditionning systems (CFC, HCFC, HFC) or in fire fighting systems, and the volatile organic compounds.

The only solution to reduce at source the sulphur oxides emissions is to minimize the sulphur content of the fuel oil used on board.

The use of environmentally sound cleaning liquids would be essential in order to prevent the emission of volatile organic compounds.

About chemical products used for air conditionning and fire fighting systems, the best solutions consist in using non ozone depleting substances, such as CFC or HCFC or halons, or in limiting their use to the just necessary (for existing ships).

B) MINIMIZATION AT SOURCE

It is likely that the gas emissions may be reduced if measures are taken to limit leaks from the air conditionning systems or to treat the pollutants issued from the propulsion systems.

A care has to be exercised in designing the propulsion system : combustion chamber optimized, use of low NOx burners, ...

C) SEGREGATION AT SOURCE AND COLLECTION

For chemical products used in air conditionning systems, it is necessary to practise a selective collection in order to facilitate the re-use and recovery procedures.

D) SHIPBOARD TREAMENT AND/OR STORAGE

Eventually, some shipboard treatment devices for the pollutants issued from the propulsion systems, such as those indicated in §.8.9, may be considered to comply with MARPOL convention quality levels.

E) ELIMINATION AND DISCHARGE

Increase the use of alternatives, recycle bottles and reuse gassious agents as much as possible.

7. Design Constraints and Shipboard Integration Aspects

7.1 General Considerations

The annexes E, F, and G are identifiying examples of a system integration and may not be interpreted as unique situations.

In general the handling of all waste streams onboard a ship have to be researched regarding the both alternatives treatment or storage. For these alternatives flow diagramms of the waste processing have to be developed.

This flow diagramms use black boxes for known or unknown technology and the interfaces have to be defined between these boxes. In a second step the boxes have to be filled with

- technology by consideration of the requirements of the defined interfaces
- COTS equipment or knowledge from land-based waste treatment plants.

If using COTS equipment integration is necessary in terms of

- Signatures
- Shock
- Electromagnetic Interference (EMI)
- Power Supply (440V/60Hz)

7.2 Space Arrangements and Equipment Layout

A) Processing location

The location for the processing of the different waste stream depends on several aspects:

- To reduce transport routes the processing equipment have to be installed as close as possible to the sources of the waste.
- The space on a warship is reserved for the military load and costs money. So the environmental protection equipment have to find space between the military equipment.
- Sometimes the processing of waste produces bad smells. So the treatment rooms for waste have to be installed as far as possible from the living and oerational areas.
- Plants that treat oily or non-oily waste water often use the force of gravity for separation. These plants only function properly on a solid foundation. These places are in the middle of the ship where the amplitude of the movement are as small as possible.

B) Access and Traffic Flow

For identifying the optimum place of the installed treatment plants and the storage rooms a traffic flow study is required. This study has to investigate the flow from the sources of the waste to the processing locations and the storage rooms. The study also includes the offloading of the waste in ports or the handing over in sea to a support ship.

When using containers or other transport equipment the doors and passages must be properly sized for the transport on a seagoing ship.The weight of this transport equipment filled up with waste must be limited when handling by one man. Otherwise it has to be handled with support systems like crans or elevators.

C) Unprocessed Waste Storing

Place for storage rooms are rare on a warship. So the processing has to be held prior to the storage of waste. The amount of the different waste streams are not well distributed over a day. So to harmonize the amount of waste for a treatment plant tanks or rooms are needed. They are also needed for times when the treatment plants are out of order for maintanence or failures. Storage rooms, e.g. for solid waste, needs great volume. This volume is left over on the bow or the stern areas. In the middle of the ship normaly no place is left for storage of waste. This causes long ways for the transport of the waste.

If the processing equipment or the support facilities in port needs the segragation of the waste it have to be separatetd into different categories. That includes the staging areas also need the separation into these categories and the different categories sometimes need a different processing with different equipment..

The staging of waste can be realised in different ways, but in general it depends on bins, racks and other restrains for holding the waste. All of them have to be made of corrosion resistant steel and have to be constructed in a way that the cleaning is very easy.

D) Handling Systems

Untreated waste is normaly transportet by the person that generates it. Possible ways are using trash bags or cans. Treated waste is stored in much larger containers that can not easily moved by one person. Especially on a seagoing ship a person is not able to handle the same weights as on land.

For offloading the waste in sea or after some days in port a handling system is necessary. It can be as simple as a handtruck and a chainfalls rigged for vertical movements on small ships to fork trucks and elevators on large ships.

E) Health and Sanitation

50% of all waste onboard is contaminated by food. It is impossible to segregate the clean waste from the contaminated waste. So the whole waste must be assumed to be food-contaminated.

Sanitation and health issues have to be considered when dealing with waste that produces odour or includes bacterias or mould. The storage areas and the used equipment should be constructed in a way to minimize the sanitation-related impacts. That means that spaces must be treated like a wet space and have to be cleaned easily.

The storage and treatment areas should be equipped with hot and cold water and also with drains that have to be tied into the greywater system. The spaces have to line by corrosion-resistant steel with no pockets at the foundations of any equipment or at the bulkheads to allow easy access for cleaning.

For food-contaminated waste chilled or frozen storage should be considered to prevent any adverse of sanitary or health impact for the storage room.

7.3 Support Systems

A) Control System

All the waste treatment systems have local control systems for their operations. These control systems are necessary for the control of the proper work of the treatment plants and supports the finding of failures. They usually based on PLC controllers and creates the possibility to send several data using an interface to the integrated monitoring control system of the ship. Using this technology the unmaned machinery room is possible.

Overthis the waste processing spaces have to be equipped with all other normal ship systems for this type of space, which includes internal communication, controls and lighting.

B) Electrical Power

Normally processing equipment for treating wastes needs small amounts of electrical power. Only advanced systems like plasma arc thermal destructors need power that influence the calculation of the electrical power plant of a ship.

Normally processing equipment requires 440V or 115V, 60 Hz 3-phased or 1-phased power.

C) Fluids (Fuel oil, Sea Water, Fresh Water, Chilled Water, Compressed Air, ...)

Several processing plants need fluids for supporting the treatment of waste. When planning the installation of this plants it has to be sure that the support with this fluid will easily be possible.

Incinerators e.g needs fuel oil for burning and an exhaust gas system. Advanced thermal destructors like plasma arc systems or SCWO system needs great amounts of sea water for cooling demands.

Fresh water is needed for cleaning procedures e.g. membran systems treating bilgewater or sewage.

Chilled water have to be need in all cooled areas where food waste will be stored for preventing the growing of odour and bacterials.

D) Ventilation

The ventilation system of storage and treatment rooms must be carefully considered. It must be ensured that odours and bacteria are kept within this spaces and that the can not ontaminate the whole ship. So the ventilation system that serving this spaces should exhaust directly to the weather.

The amount of fresh air brought into this spaces has to calculate the demand for the treatment processes into this rooms. E.g. a sewage treatment plant need air for the areation of the bioreactors. The system should also be balanced to a negative pressure to make sure that odour and bacterias will not escape to the rest of the ship.

E) Firefighting

Paper, cardboards and especially plastics are significant fire hazard onboard a ship. The areas where this materials are treated and stored have to be equipped with adequate fire protection e.g sprinkling systems or portable CO2 fire extinguishers. As part of the fire-fighting system the spaces have to be equipped with high-temperature alarms that sounds in the central control station to warn of a fire in these spaces.

7.4 Vulnerability

A) Signature

Signature reduction is typical for all advanced warships. So every plant or system on a modern warship ise able to influence the signature of the combatant.

By installing processing equipment onboard a warship noise signature and IR-signature have to be named. On modern anti-submarine warfare combatant all large noise sources must be isolated. If the reduction of noise emission can not be reduced the plants must be switched off during special operations.

IR-signature is used by anti-ship missiles. Iincinerators or other advanced thermal destruction systems have a several impact on the IR Signature. A possible reaction is to mix the hot exhaust gas with cool air. For many modern combatants the IR Signature can be a real problem that must be seriously considered prior to selecting any thermal system.

B) Electromagnetic Interference (EMI)

EMI is normally not a consideration for waste treatment plants. However systems use high-power electrical arc like plasma arc systems or systems that are steered by frequenc-controlled processes will have problems.

C) Shock

The processing equipment of a combatant is not mission critical for the ship. So the equipment must not work anymore after shock from e.g. a underwater explosion. But it must be ensured sure that no person will be endangered by broken parts from the equipment.

In NATO navies this circumstance indicates a shock hardening refering to the Grad B. Processing equipment that is commercial off the shelf is normally not constructed for this shock load. It must be tested and hardend against shocks to make it suitable for the use on a warship.

8. RECOMMENDATIONS FOR WASTE MANAGEMENT PRACTICES (OPTIONAL)

8.1 GENERAL CONSIDERATIONS

The aim of this part of the AMEPP is to provide some examples of recommendations for waste management practices that could be applied by designers (principle of operation with diagrams, size, weight, nature of processed waste, ...).

Starting from these strategies, more accurate information on a wide range of treatment options may be available in the AMEPP n° 3 which give some examples of equipments tested or currently being installed by many NATO navies.

Annex H gives some other examples of detailed information about these possible equipments.

8.2 OILY WATER

According to IMO Resolution MEPC 60 (33), the oily water separator might be :

- separation of oil and water using coalescence and decantation by gravity;
- separation using coalescer filter;
- parallel plate separators;
- membrane filter (ceramic or polymeric).

or all combination of these units.

8.3 BLACK WATER

- vacuum collection and hold on board prior to discharge (where permitted);
- vacuum collection and aerobic biological treatment (with or without grey water);
- treated liquid discharge, biological sludge retained on board prior to discharge (where permitted) or incineration (taking into account MARPOL Annex VI);
- aerobic biological treatment (with or without grey water); treated liquid discharge, biological sludge retained on board prior to discharge (where permitted) or incineration (taking into account MARPOL Annex VI);
- aerobic biological treatment (with or without grey water) and chlorine or UV disinfection of treated liquid prior to discharge, biological sludge retained on board prior to discharge (where permitted) or incineration (taking into account MARPOL Annex VI);
- physical separation process and discharge (where permitted);
- chemical treatment process (oxidation) and discharge (where permitted).

8.4 GREY WATER

Currently there are no MARPOL regulations that prohibits the discharge of grey water. These management practices are optional.

- collection and hold on board prior to discharge (where permitted) or shore-based disposal;
- vacuum collection + either option above :
  - chemical treatment and overboard discharge (where permitted);
  - aerobic biological treatment process (with black water; see black water);

8.5 FOOD WASTE

- grinding/pulping with sea water or fresh water in the galley and discharge (where permitted);
- grinding/pulping with sea water or fresh water in the galley, solid-liquid separation with water press and filters; treated liquid discharge, solid residue temporary storage;
- grinding in the galley without water, storage in a holding pressure tight tank without air and disposal to port facilities;
- incineration of solid residues issued from a solid/liquid separation (taking into account MARPOL, Annex VI), incinerated-ash discharge (cruiser liner example)).

8.6 SOLID WASTE

Collection containers and Techniques :

- A swap system is based on swapping full containers with empty ones. It requires that ships have two or three full sets of collection containers. The number is determined by the time it takes to have returned the empty ones.
  This system can be used if the Navy designs central collection areas for recyclables and disposal of segregated wastes by alternative processes. Space allocation for waste collection will be at a minimum. Creative solutions for stacking trash containers and store recyclables will be needed.

- In a liner system, the collection containers remain in place. All containers have clear or colorcoded transparent liners placed in them. The liners are removed and the bags of recyclables and segregated trash are collected in collection carts for transport to a designated space. The liners could even be biodegradable for processing organic waste.

A wide variety of recycling containers and equipment is available from different vendors. Some equipment will be necessary for transporting, processing and storaging the materials that are collected. Some materials will be kept for recycling back on shore or fed into subsequent disposal systems. Balers are machines used to compress recyclables into bundles to reduce volume and make them easy to transport.

Crushers/densifiers are special devices that crush metal cans or glass into smaller units. A grinder, or chipper, can handle wood and organic waste, taking large pieces and breaLing them down into small uniform chips.

Hammermills are a type of crusher or shredder used to break up materials into smaller pieces. Shredders exist for many materials, including ones that shred and pulversize mixed solid waste, often in conjunction with incinerators.

The latter technology, together with compacting (and heat if plastics from the whole or part of the waste), is currently being installed by many Navies.

Examples of management practices recommendations with respect to plastics:

- compacting (low level of volume reduction) and storage on board of treated plastics;
- shredding and compacting and storage of the treated plastics on board;
- shredding and compacting with heat (increased volume reduction) and storage of the treated plastics in special designed containers on board;
- incineration (taking into account MARPOL, Annex VI).

The storage procedures may be improved by the use of rooms cooled to a temperature compatible with the reduction of biological hazards.

Future treatment options will include thermal/oxidation processes which will be designed to safely destroy a wide variety of solid wastes, including plastic on board ships. This will eliminate the need for on board storage space, and the operational difficulties and cost of disposal to port facilities.

Examples of management practices recommendations with respect to recyclable wastes (cardboard, paper):

- compacting (when volume reduction is possible) and discharge of special designed containers (where permitted);
- grinding, compacting (when volume reduction is possible) and storage of the treated wastes on board;
- grinding, compacting (when volume reduction is possible) and discharge of purpose designed containers (where permitted);
- pulping (small amounts with food wastes) and discharge (where permitted);
- incineration (taking into account MARPOL, Annex VI).

Examples of management practices recommendations with respect to glass, metal and other non-plastics:

- grinding (particularly glass bottles);
- shredding, crushing and discharge in special designed bags (where permitted);
- incineration with the exemption of metal and glass (taking into account MARPOL, Annex VI)

8.7 MEDICAL WASTE

None;

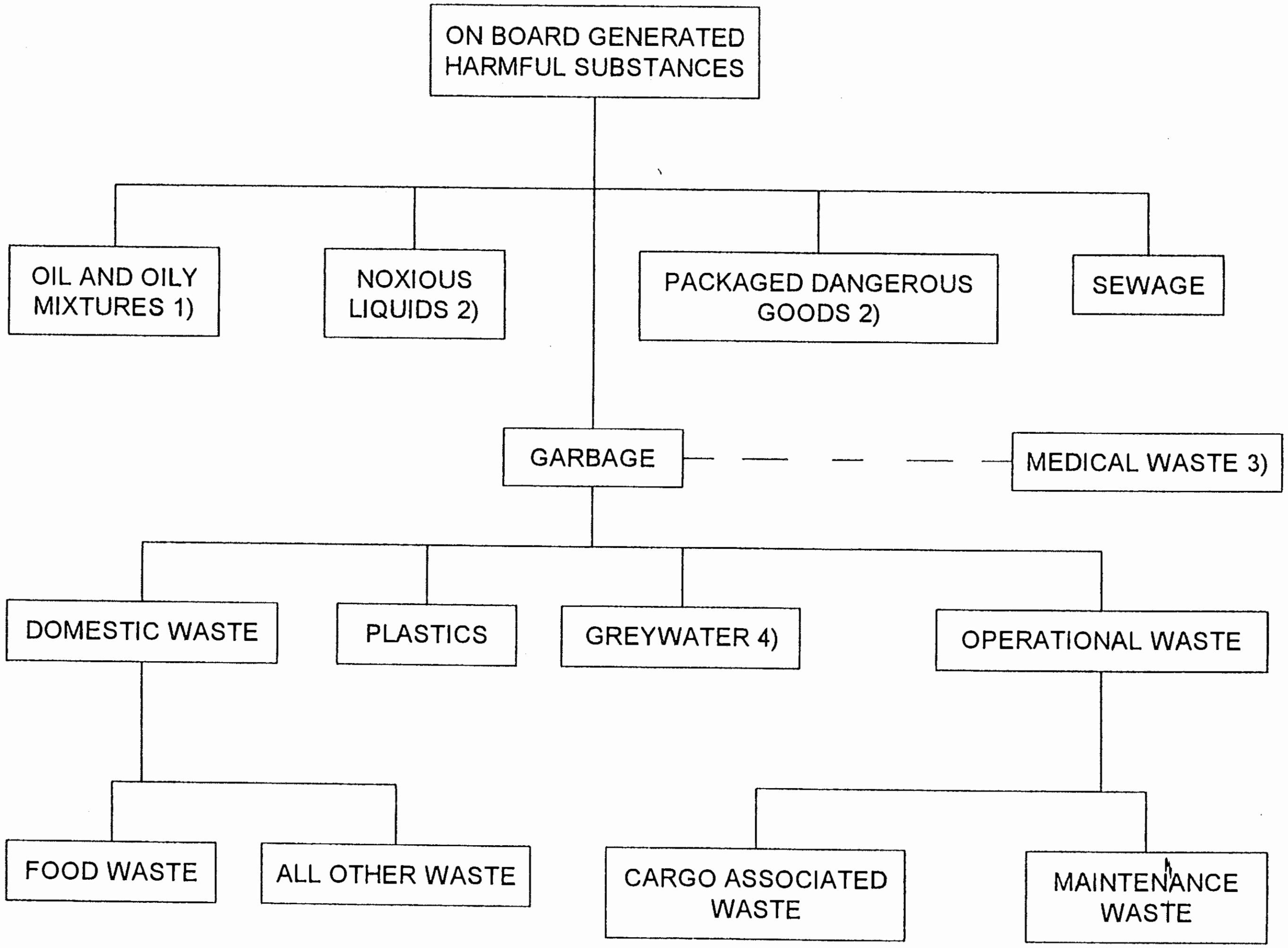
8.8 HAZARDOUS WASTE

None.

8.9 GASEOUS EMISSIONS

- For SOx/NOx emissions, a first stage treatment by injection of ammonia or urea may be considered, and if necessary, a second stage treatment by using selective or non selective catalytic reduction;

Classification of MARPOL harmful substances groups

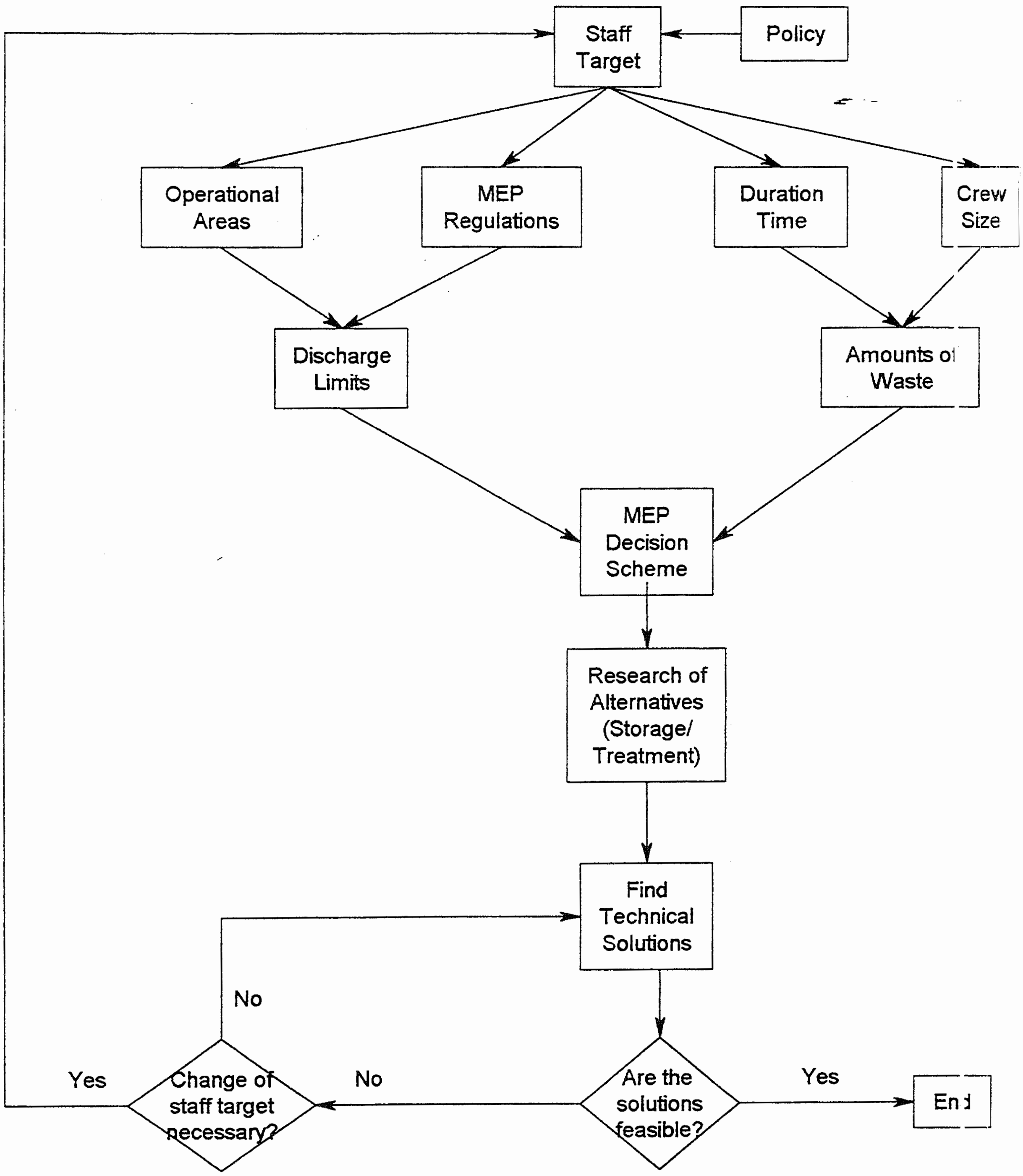


1) Including bilgewater and oily water emulsions.

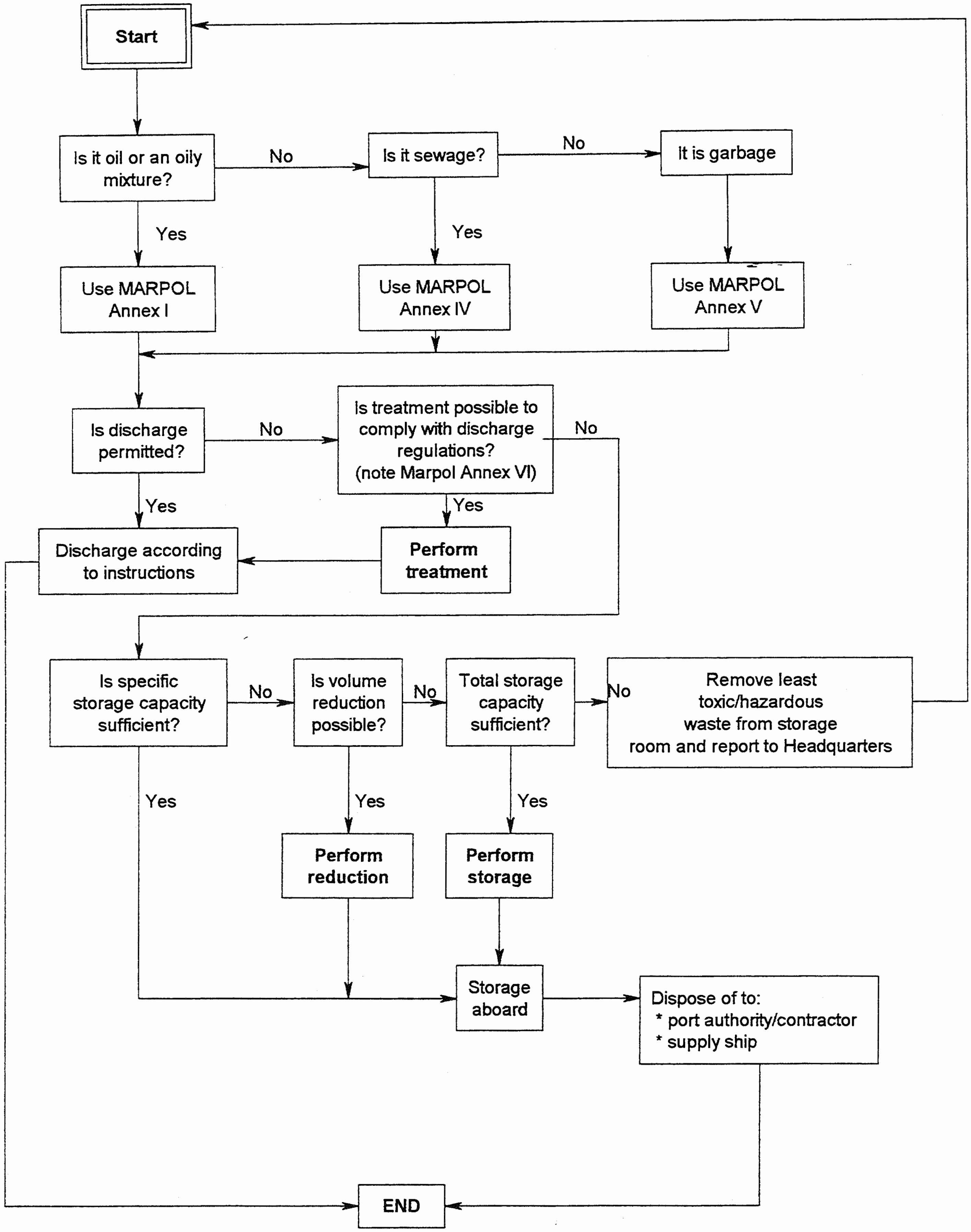
2) Not of any importance for NATO navies, because it covers transport over the seas for trade purposes

3) Not as such mentioned in the MARPOL Convention

4) For this category of waste no discharge regulations are mentioned in the MARPOL Convention

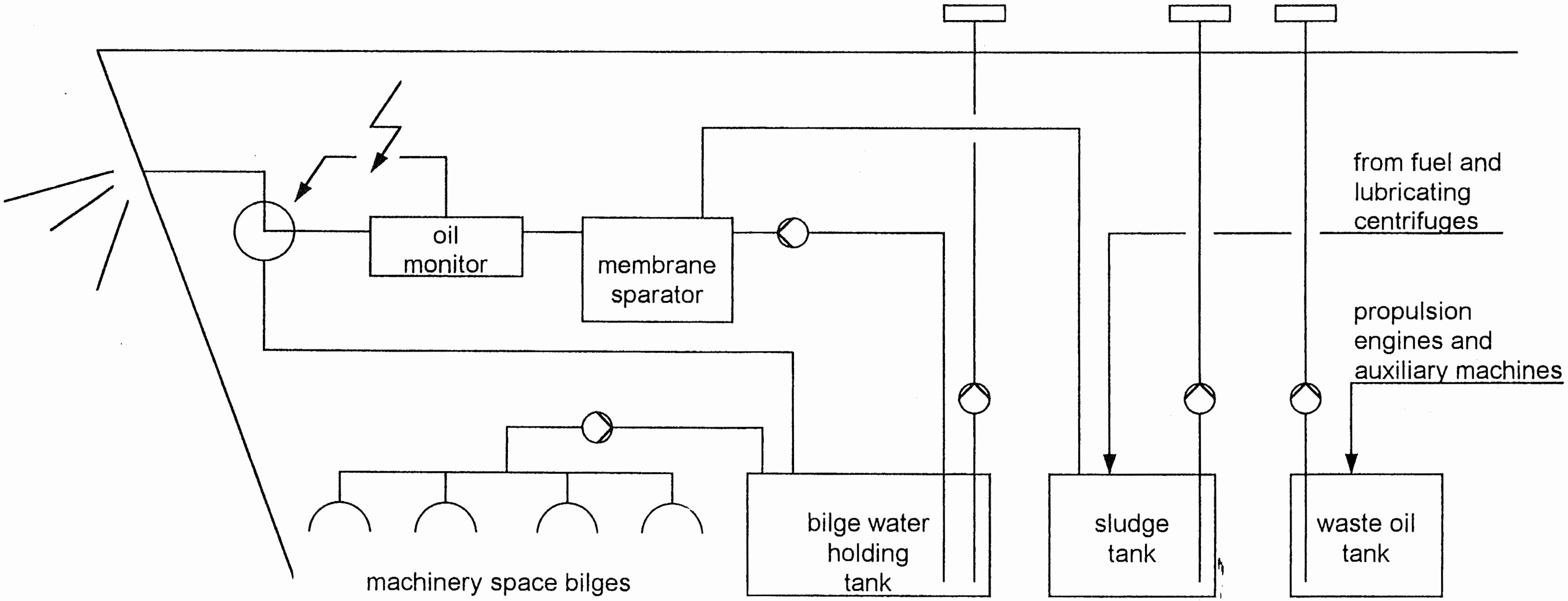

Staff Target
Policy
Operational Areas
MEP Regulations
Duration Time
Crew Size
Discharge Limits
Amounts of Waste
MEP Decision Scheme
Research of Alternatives (Storage/ Treatment)
Find Technical Solutions
Are the solutions feasible?
Yes
End
No
Change of staff target necessary?
Yes
No

Maritime Environmental Protection Decision Scheme



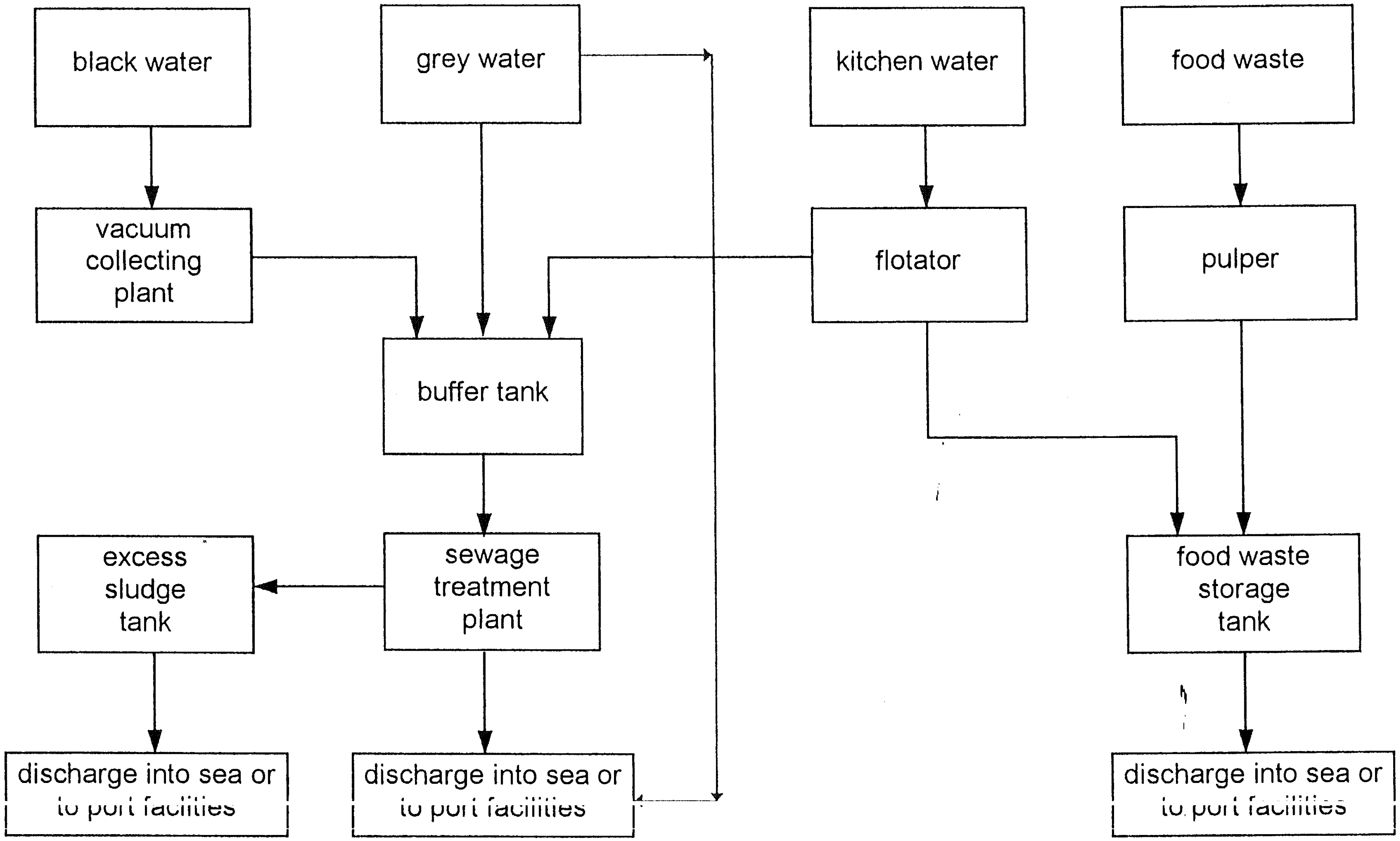
Annex C

Figure 6A: Oily waste management



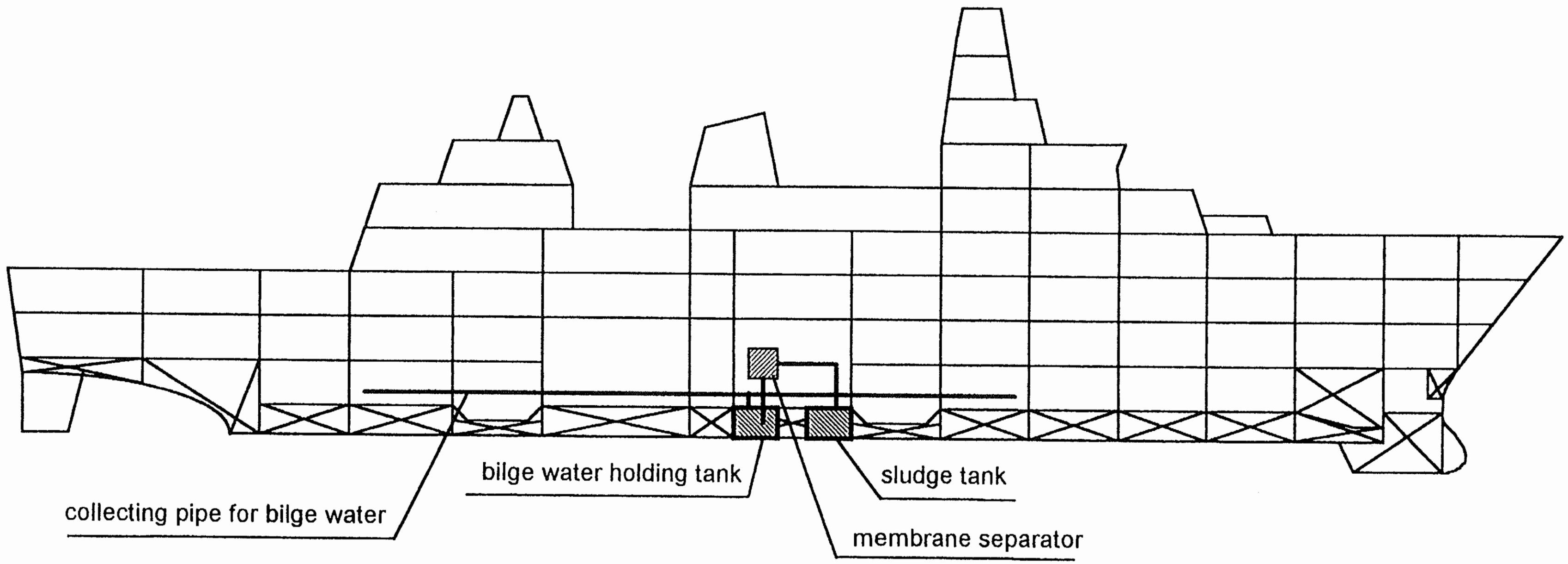
Annex D

Figure 6B: Non oily wastewater management



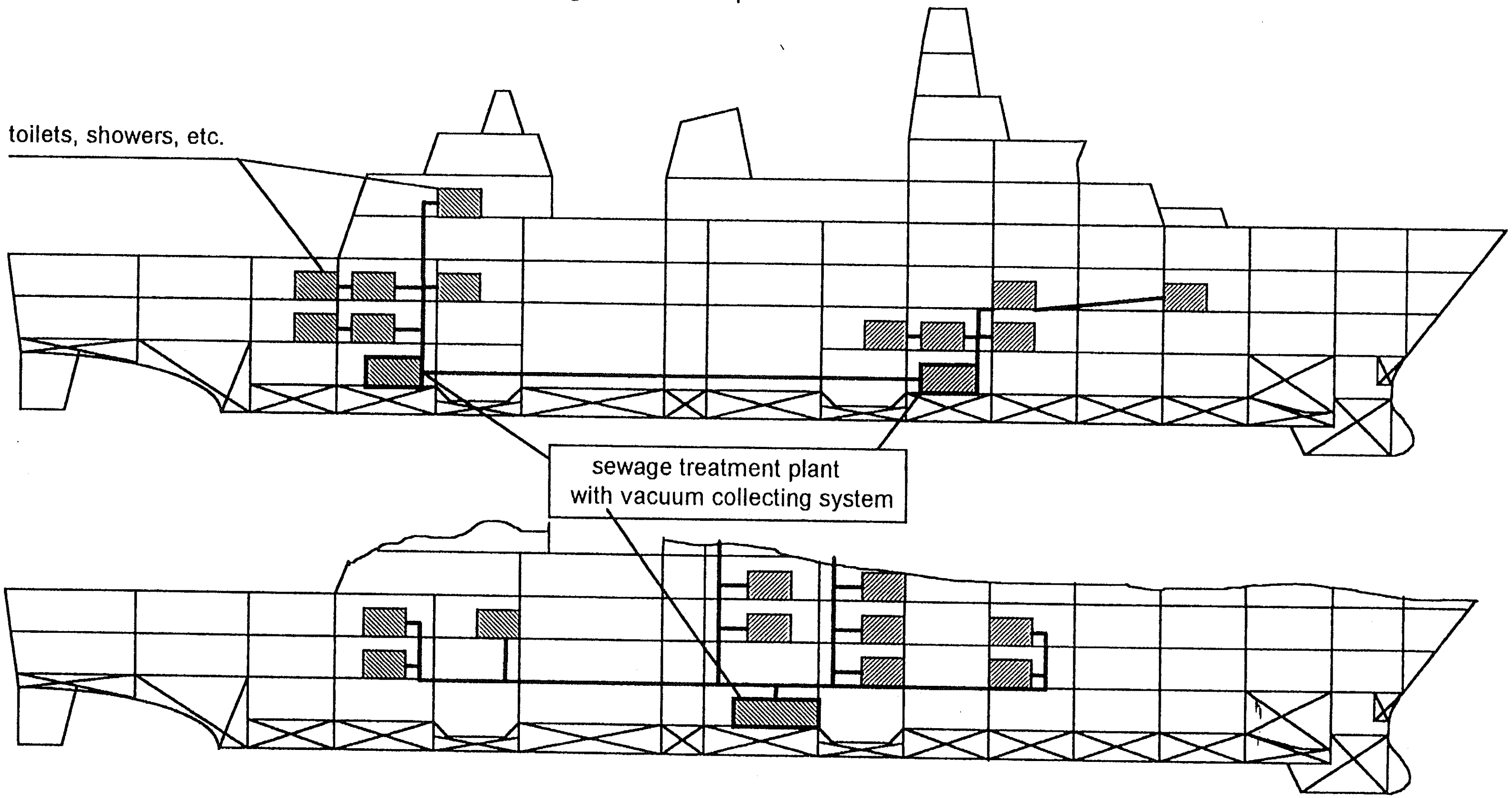
Annex E

Figures 7A: Integration of the bilge water treatment plant



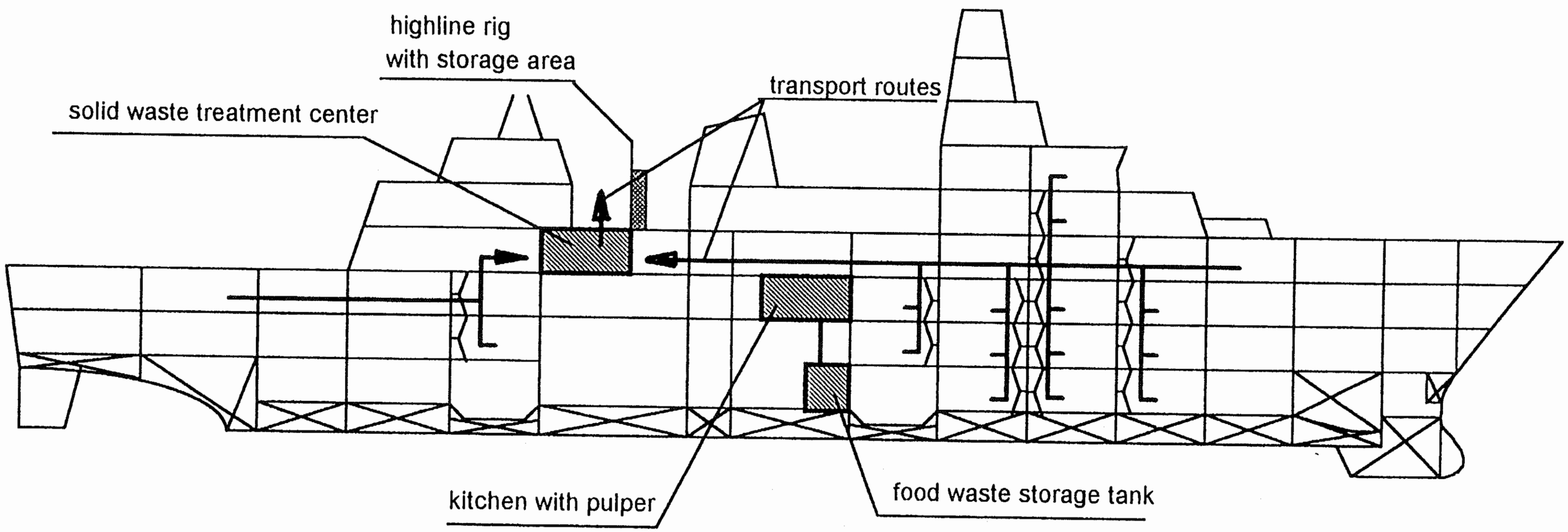
Annex F

Figure 7B: Integration of the non oily waste water treatment
Example with one and two sewage treatment plants



Annex G

Figure 7C: Integration of the solid waste treatment



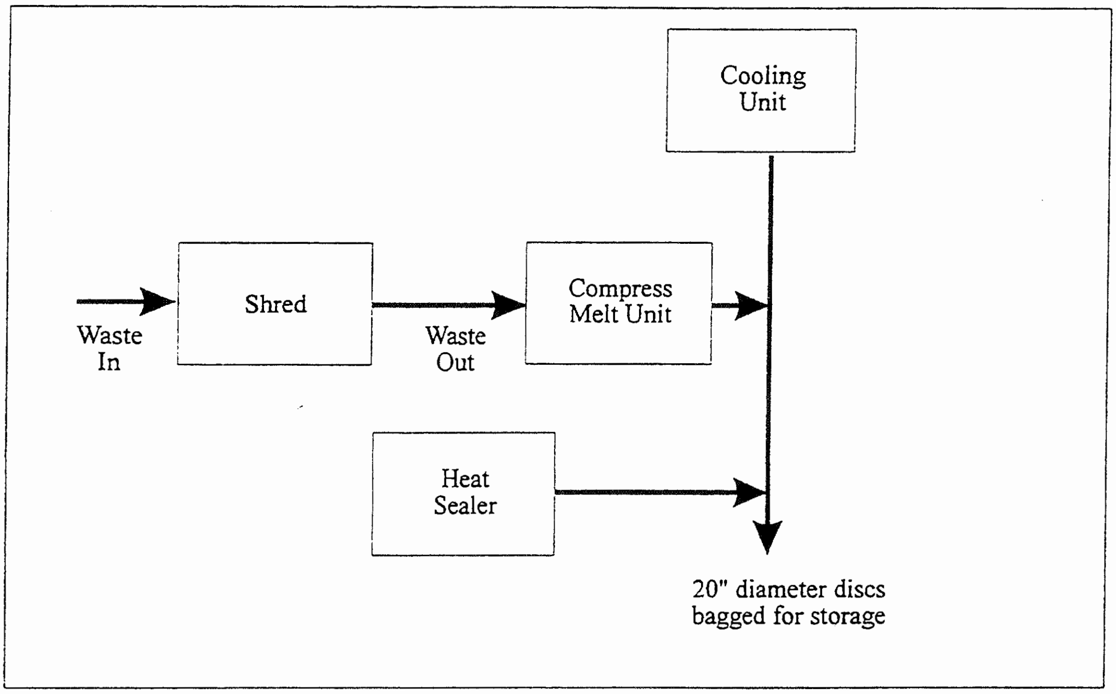
Annex H: List of examples of detailed information on a wide range of treatment options

Plastic Waste

Plastic Waste Processor (Batch operation)

Plastic waste (including food-contaminated plastic) is fed into a shredder (figure 8A). Shredded plastic is fed into a compress/melt unit. A 20" diameter disc is produced for easy long-term storage on board ship. The disc can also be sealed into a plastic back. The ship integration profile: dry weight is 1.5 tonnes, operating weight is 1.5 tonnes, total volume for the shredder, compress melt unit, cooling unit and heat sealer (including access) is 17 m^3. This does not include the stowage for the processed plastic disks.

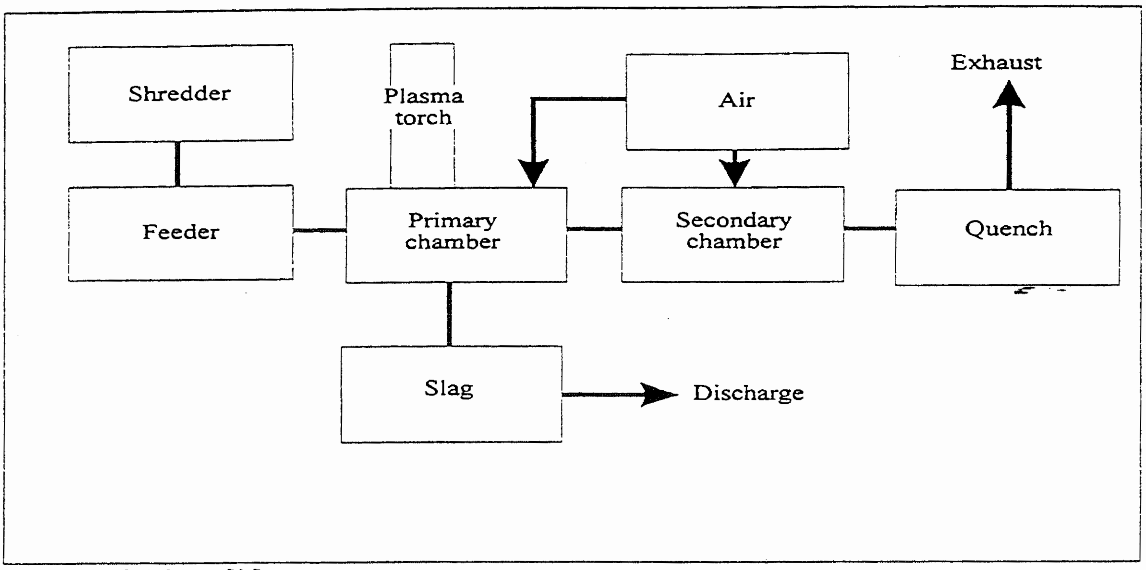
Figure 8A Principles of operation. Reduce volume of plastic waste for shipboard storage.



Plasma-Thermal (Batch operation)

The principle of the plasma-thermal waste disposing, see figure 8B, is to eliminate the need for storage on board. Electric energy is used to melt the inorganic components and to vaporise organics. Air supplied in two stages to burn the organic to CO_2 and H_2O. Chlorinated hydrocarbons for HCL. Inorganic constituents form a non-leaching slag, usually collected at the end of the shift. Commercial equipment needs to be re-designed for shipboard use (minimise weight and volume). Verify shock resistance. Equipment characteristics (design goals) are: dry-weight is 10 tonnes, operating weight is 10.5 tonnes, total volume (including access) is 200 m^3.

Figure 8B Principle of operation. Plasma Thermal waste disposal. All solid waste, plus concentrated sludges from liquid wastes

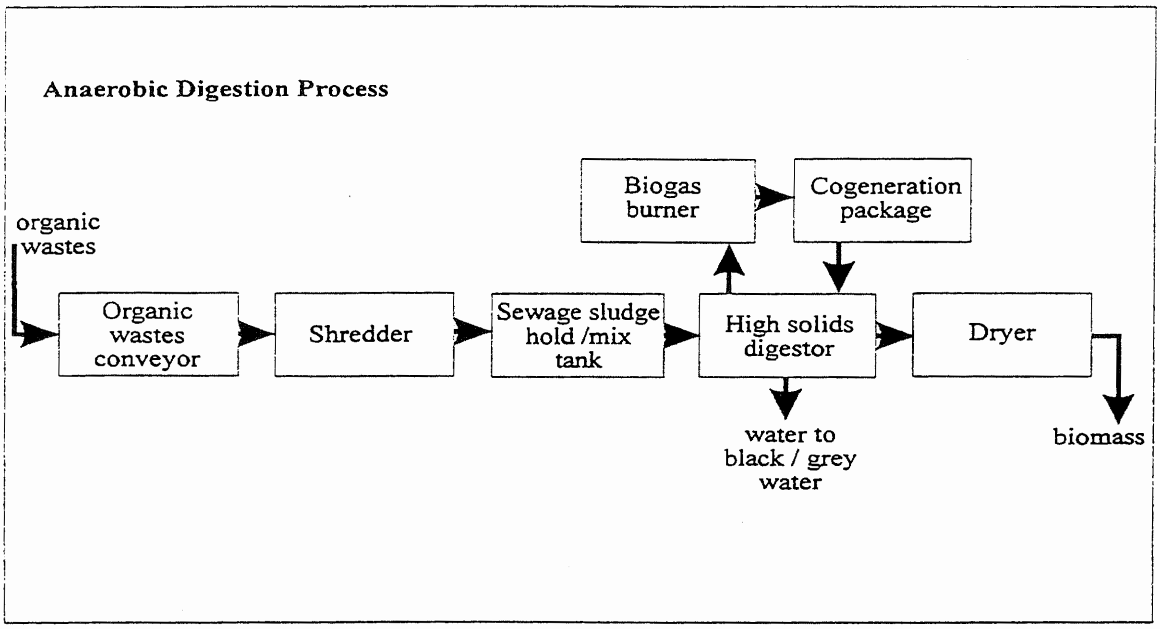


- **Recycleble solid waste**

Biological Treatment

Biological treatment is directed at wastes which contain organic matter in high concentrations. Colloidal and dissolved substances are removed by secondary, or biological, treatment where the micro-organisms of the process utilise the waste material for food. Digestion, specifically used for food and other degradable wastes, reduces the volume and the pathogenic organisms. Sludge is thoroughly mixed and digestion can be aerobic or anaerobic.

Figure 8C Principle of operation. Biological treatment for volume and COD reduction of food/degradable wastes for permitted discharge overboard.



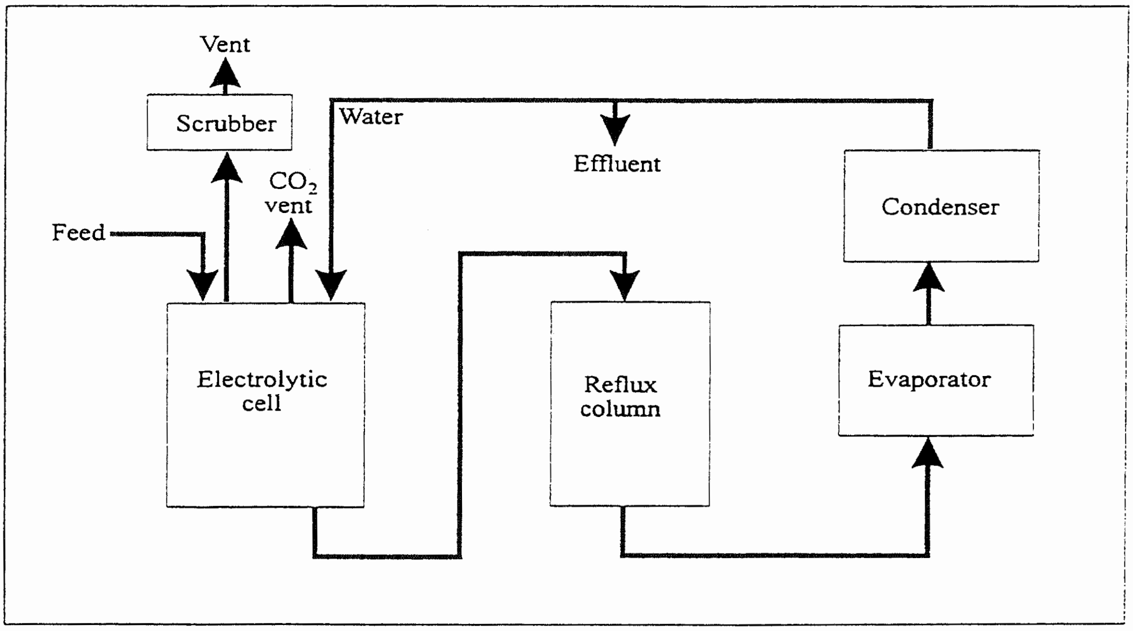
Digested sludge is reasonably inert and has a high water content. It can be de-watered by filtration or drying and the dried sludge incinerated, used for landfill or discharged into the sea.

Aerobic digestion allows the aerobic micro-organisms to oxidise organic matter within the sludge to carbon dioxide, water and biomass. The aerobic stabilisation process is relatively easy to operate and produces a fairly clear supernatent liquor. Anearobic digestion occurs in closed tanks. It comprises a series of complex interrelated biochemical reactions, performed by groups of micro-organisms functioning in the presence of free oxygen. Under controlled temperature, pH and high solids loading, the anaerobic micro-organisms convert a major portion of the organic matter. Important to note is the danger of contamination of chlorine-based cleaning compounds which could kill the organic matter.

Biological treatment plant readily used for sewage (anaerobic plants at pilot scale)

Ag(II) mediated electrochemical oxidation (developmental systems for shipboard use)
An electrolyte consisting of nitric acid containing Ag(I) ions is circulated through a divided electrochemical cell. At the Pt/Ti electrode, reactive Ag(II) is formed, which reacts in its turn either directly with organics being fed to the system or with the water in the electrolyte to form species such as OH radicals, which also react with the organics. The ultimate CO_2, inorganic species (such as sulphate and phosphate) and H+ ions. The H+ ions cross the dividing membrane in the cell to the catholyte, thereby carrying the cell current. At the stainless steel cathode, the H+ ions and nitrate react to form nitrous oxide and NO_x.
The reduced species are reformed into nitric acid by reaction with air or oxygen in a regeneration system and fed back to the electrode. The gasses leaving the systems are cooled and scrubbed as required to ensure that no NO_x, acid fume, etc are released to atmosphere. Inorganic species are removed by evaporation from the catholyte system. The process can be run in either a batch or continous mode and can handle up to 95% (substrate depent) water in the feed.

Figure 8D Principle of operation. Oxidation of organics to form carbon dioxide, water and inorganic species.

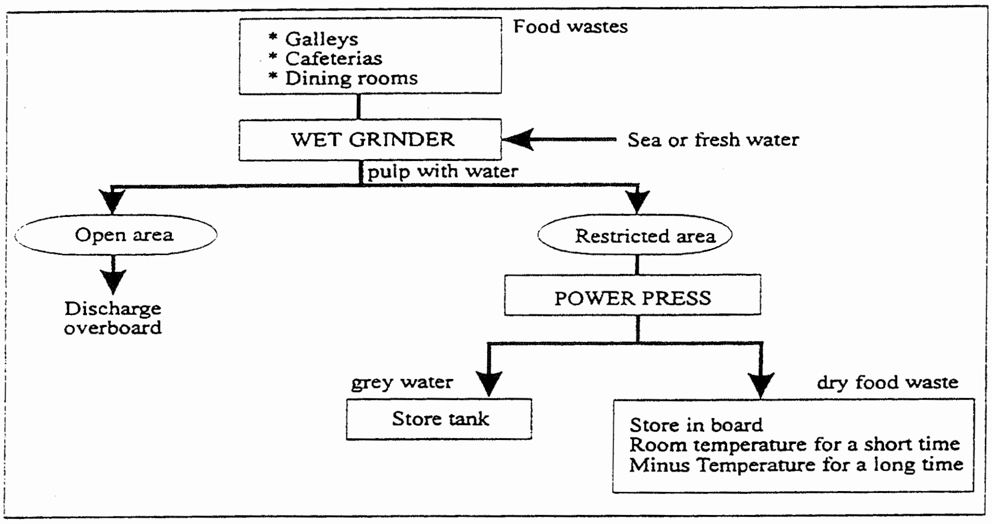


- **Food waste**

Wet Maceration (wet grinder and power press)
The Wet Maceration wet grinder and power press is being installed to process all food wastes generated on board a ship (figure 8E). Food waste is ground with sea (or fresh) water in a wet

grinder into a pulp. Pulp is discharged directly into the sea, if the area is open. If the area is restricted, the power press separates pulp and water: the grey water and the pulp are stored on board. Plastic waste linked with food waste (eg plastic ramekins) but only when the waste can be discharged alongside the quay (eg when ships are in port). Extra facilities are storage before discharge into open sea, all pipes and equipment have to be desinfected after each meal. Equipment characteristics are: dry weight is 1.5 tonnes, operating weight is 2 tonnes and the total volume (including access) is 15 m^3.

Figure 8E. Principle of operation. For processing all food wastes generated on board a ship.



- **Solid waste (general)**

Pyrolysis and Combustion
The destructive distillation by action of heat in an oxygen deficient atmosphere (1st step). First step: Pyrolysis of the organic materials. Second step: Finer residual particles are burned together with the pyrolysis gas and entrained particulate matter in a special combustion chamber at high temperature (figure 8F). The secondary wastes produced are flue gas, ash, metals, inerts, reaction products from flue gas cleaning.

Thermolysis of Solid waste
The solid waste is shredded to 200 mm, eventually dried, and air-tightly fed into the thermolysing unit (electric rotating drum). The thermolysis process takes place without oxygen at atmospheric pressure and in a range temperature of 400 - 500 °C (figure 8G).If secondary wastes are produced: a solid carbonate residue (coke) and gases. The coke is washed while inert are separated by gravity. The filtration of the aqueous suspension produces inert combustible coke while the process water is treated by conventional water treatment. The produced gases are steam and energetic heavy gases: tars and incondensibles.
A post-combustion chamber is provided for burning heavy gases in order to produce energy and to reduce the pollution level at atmospheric exhaust.
The secondary wastes produced are low pollutant exhaust, inert (glass, metal), combustible coke, chlorine in process water (if wastes contain chlorinated plastic).

Figure 8F Principle of operation. Pyrolyses and Combustion. Destructive distillation by action of heat in an oxygen-deficient atmosphere

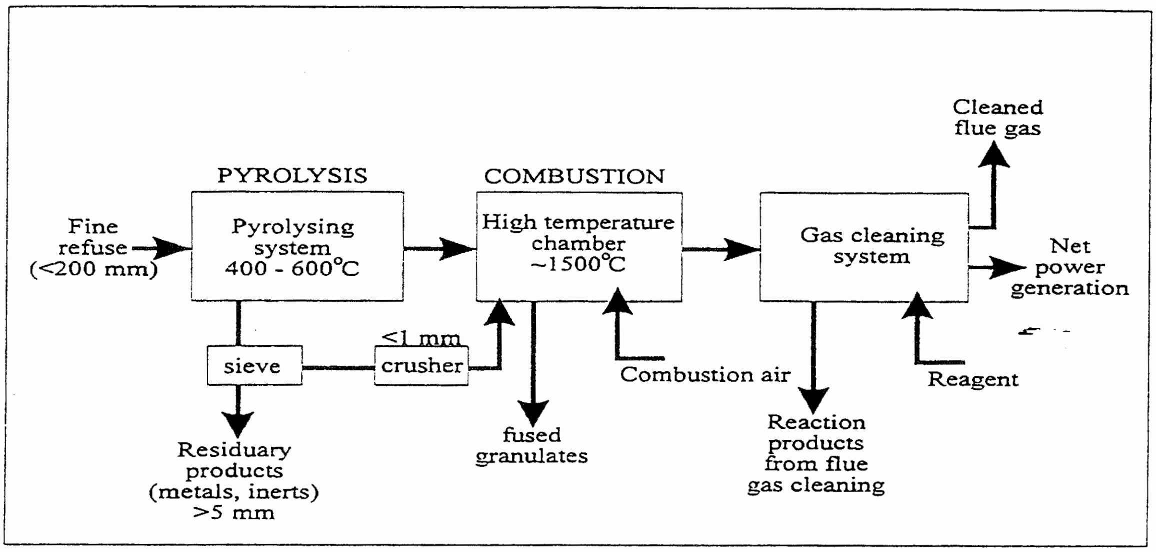
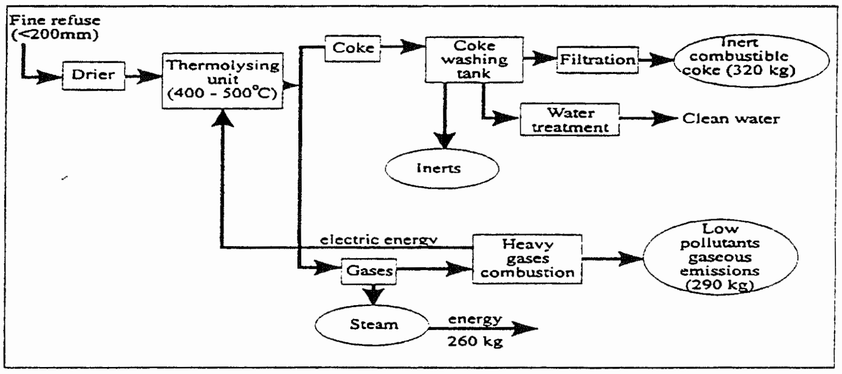


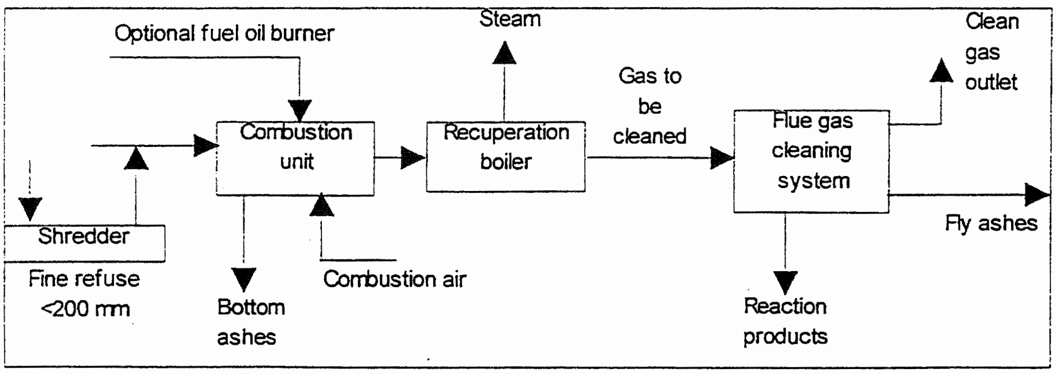
Figure 8G Principle of operation. Thermal destruction without oxygen at 400 - 500 °C and atmospheric pressure.



Conventional incineration or combustion in a fluidised bed

The bulky or shredded wastes are burned either in a convention combustion unit or in a fluidised bed (figure 8H). Bottom ashes are collected under the furnace. A recuperator boiler could allow heat recovery and electric power generation by steam production. Then the gases, laden with dust, may be neutralised by a reagent and filtered. Active carbon may be used to absorb dioxins. Fly ashes and reaction products are gathered at the base of the gas cleaning system.

Figure 8H Principle of operation. Combustion unit plus flue gas cleaning systems.



- **Sewage**

Ultrafiltration/microfiltration
Feed is circulated through a membrane module in which it flows tangentially to the membrane surface (figure 8I). The membranes can be made in form of tubes, flat sheets or spirals. They are most frequently made from polymeric materials, although there are some inorganic membranes. Membranes operate by a sieving action.
Water and small molecules pass through while larger species are retained. Tangential flow helps to improve permeation rates by keeping the membrane surface clear of deposited material.

Figure 8I Principle of operation. Volume reduction of solids. Removal ~~of~~ BOD and micro-organisms.