REGIONAL MARINE POLLUTION EMERGENCY
RESPONSE CENTRE FOR THE MEDITERRANEAN SEA
(REMPEC)

ACTIVITY 3

OPTIMUM SOLUTIONS FOR COLLECTING, TREATMENT AND DISPOSAL OF RELEVANT SHIP-GENERATED SOLID AND LIQUID WASTES IN ALBANIA, CROATIA AND SLOVENIA

FINAL REPORT

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Activity 3: Optimum solutions for collection, treatment and disposal of relevant ship generated solid and liquid wastes in Albania, Croatia and Slovenia

Final Report

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Tebodin B.V.

Drienerstate, P.C. Hooftlaan 56 / Laan van Nieuw Oost-Indie 25
7552 HG Hengelo / 2593 BJ The Hague
P.O. Box 233 / P.O. Box 16029
7550 AE Hengelo / 2500 BA The Hague
the Netherlands

telephone + 31 74 2 49 62 28 / +31 70 348 02 98
telefax + 31 74 2 49 62 15 / +31 70 348 05 16
e-mail j.kleinwolterink@tebodin.nl / a.schoof@tebodin.nl

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1 Introduction

1.1 Project background

The implementation of MARPOL 73/78 Convention for prevention of pollution from illegal discharges into the sea is one of the main concerns relating to prevention of the pollution from ships in the Mediterranean Sea. Even though accidental marine pollution still attracts major public attention, operational pollution by illegal discharges into the sea is the main source of pollution by ships of the marine environment.

The IMO/UNEP Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), a Regional Activity Centre within the Mediterranean Action Plan (MAP) of the United Nations Environment Program (UNEP) administered by the International Maritime Organisation (IMO), is currently implementing an EU funded MEDA Project on port reception facilities for collecting ship-generated garbage, bilge waters and oily wastes in the Mediterranean (MED.B7.410097.0415.8). As the MEDA project does not cover the whole Mediterranean region, REMPEC is currently executing a similar Project in three other countries which are not Euro-Med partners, namely Albania, Croatia and Slovenia. Financial support for the Project's analogous activities was provided by UNEP/MAP Mediterranean Trust Fund (MTF) budget. Like the MEDA Project, this Project also aims at promoting the installation of port reception facilities in accordance with Annex 1 and V of MARPOL 73/78.

Activities 1 and 2 of the project aimed at assessing (by consultants and national experts) the present situation in the involved countries concerning port reception facilities and at identifying required capacities for collection and treatment of relevant types of solid and liquid wastes (Activity 1) and oily ballast waters from tankers (Activity 2). The implementation of these two activities has been completed.

The results of above mentioned two activities will provide the basis for Activity 3, the contents of this report. Activity 3 of this project contains a study concerning optimum solution for collecting, treatment and disposal of relevant types of ship-generated solid and liquid wastes for relevant ports/terminals of the three beneficiary countries involved, including cost recovery recommendations.

1.2 Methodology

1.2.1 Briefing Mission

On 19th and 20th January, a Briefing Mission between representatives of REMPEC and the Consultants was undertaken at the premises of REMPEC. During this meeting, the project objectives and expectations were further explained and fine-tuned. In addition a lot of project background was provided by REMPEC, including contact details of relevant persons and institutes. Tebodin gave a short introduction of its experience in the field of port reception facilities and earlier IMO assignments as far as relevant to this project.

An important issue refers to the requirements for the contents of the report and its reporting style, since it should allow all Mediterranean countries to get much more acquainted with the range of available port reception facilities and techniques used.

1.2.2 Clarifications with regard to Activities 1 and 2

Tebodin read the reports of Activities 1 and 2 in detail and has put forward several questions to the Consultant, who compiled these reports. In general, the reports are quite an achievement and are well presented in a standardized format. It is fully understood, that the analyses performed are partly based on data as issued by the respective authorities on one hand and own estimates on the other hand.

Although we clearly understand the difficulties of receiving standardized information from this report, we identified several open endings and or missing data, which are mentioned in the footnotes of the tables as attached to this report. Nevertheless, we got full support and understanding from Environmental Protection Engineering S.A. (E.P.E.) in Greece in terms of clarifications about the contents of the two reports.

1.2.3 Desk study

During the Briefing Mission it was agreed, that the data as were issued in both reports 1 and 2, will be used as a basis for the analyses of Tebodin. A number of summarizing tables has been developed by Tebodin based on these reports and are used for further analyses and selection of most appropriate type, size and costs of port reception facilities. These tables are enclosed in Annex A.

This report has been compiled predominantly based on Tebodin's own knowledge and working experience about port reception facilities in many ports worldwide as well as waste management techniques (BAT – Best Available Techniques).

To visualize information on treatment technologies, we have included many illustrations in our report. Some illustrations come from plants in operation, others from suppliers of equipment. The Consultants wish to state that Tebodin maintains an independent position to the suppliers of equipment, and that use of these illustrations does neither imply any kind of endorsement of these suppliers, nor a disqualification of any other supplier.

1.2.4 Reporting

This report addresses the requirements of a number of ports in the three Mediterranean countries Albania, Croatia and Slovenia.

2 Summary of results of Activities 1 and 2 as basis for Activity 3

2.1 Facilities for oily waste

The reports on Activity 1 and 2 concluded that for oily waste facilities are adequate exist in a number of ports. For several other ports it is recommended to provide minimal collection services by truck without establishing treatment facilities. Services may be provided by private contractors or the Port Authority. It is recommended that the collected oily wastes are transported to an approved disposal facility, but it appears that such facilities do not exist at the moment. Table 1 provides an overview.

Table 1: Ports with adequate facilities or minor improvements

Country	Adequate facilities exist	Minimal collection services recommended
Albania[1]	Durres	Saranda, Shengjin, Vlore
Croatia[2]	Dubrovnik; Ploce; Plomin; Rijeka-Rasa; Sibenic, Split; Zadar	Enlarge storage capacity of Omisalj and consider new treatment facilities
Slovenia	Koper	

For other ports, new facilities are proposed or it is recommended to improve the existing facilities. The recommendations for these ports are listed in the table below. The port of Koper in Slovenia has adequate reception facilities available and is therefore not included in the table below.

Table 2: Recommended facilities in ports

Country	Port	Recommended facilities for oily waste
Albania	Saranda	Collection: road tankers or road tanker + barge are advisable. Treatment: approx. 20 m^3 holding capacity to be installed, treatment takes place in licensed nearby facilities or in the country's refineries.
	Shengjin	Collection: road tankers or road tanker + barge are advisable. Treatment: approx. 20 m^3 holding capacity to be installed, treatment takes place in licensed nearby facilities or in the country's refineries.
	Vlore	Collection: road tankers or road tanker + barge are advisable. Treatment: approx. 20 m^3 holding capacity to be installed, treatment takes place in licensed nearby facilities or in the country's refineries.

1 Albania is not a signatory party of MARPOL 73/78. The ratification of MARPOL is assumed to be effective for this particular study.

2 The Ministry of Maritime Affairs Transport and Communication of Croatia is incited to develop a Waste Management Plan for the ports of the country

Country	Port	Recommended facilities for oily waste
Croatia	Omisalj	Collection: OK. Treatment: The installment of a 7,000 m^3 reception tank and a 1,000 m^3 slop oil tank is proposed. Furthermore it must be defined to which extent new treatment facilities should be installed (e.g.): • Water treatment 100 m^3/h • Slop oil treatment • Treatment of residual sludge Recovered oil may go to a refinery in Rijeka. It is strongly recommended to thoroughly study the design of both the reception-storage and the treatment facilities.
	Ploce	Collection: is outdated, improvement measures are recommendable. Treatment takes place in open equipment without any secondary treatment: The rehabilitation of the old equipment is recommended and secondary treatment equipment should be added.
	Rijeka-Rasa	Collection: is outdated, improvement measures are recommendable. Treatment takes place in an open API separator 750 m^3/h without secondary treatment: The installment of new treatment facilities for secondary treatment are recommended: • Water treatment 750 m^3/h • Treatment of slop oil and sludge Recovered oil may go to a refinery in Rijeka. It is strongly recommended to thoroughly study the design of both the reception-storage and the treatment facilities under the given limiting parameters of logistics and infrastructure

In grey: interpretations by Tebodin

The report on Activity 1 provides conceptual flow diagrams regarding the proposed facilities, but they do not elaborate on the appropriate type of treatment technology. This will be addressed in this study.

2.2 Garbage

With respect to garbage, the following conclusions are presented in the report on Activity 1. Adequate facilities are present in all ports, with the exception of:

- Saranda, where receptacles are recommended;
- Plomin, where the separation of food waste is recommended.

3 Review of currently available technologies for oily wastes

This chapter provides an overview of options for collecting and treatment of wastes from ships. Also options for final disposal are discussed. Collection, treatment and final disposal are addressed in separate sections. These sections conclude with an evaluation of the various options and provide recommendations on the selection of appropriate technology. We have endeavored as much as possible to keep the description of the various treatment options readable for those who do not have a technical background in waste (water) treatment. We have therefore not elaborated the fundamentals (physics and/or mathematics) of the treatment processes, but included pictures or practical examples whenever possible.

3.1 Types and composition of oily waste

Ship-related operational oily waste can come from numerous sources. Annex I of MARPOL 73/78 contains certain regulations and interpretations related to procedures for the retention onboard, treatment, discharge at sea and disposal of oily mixtures generated in the machinery spaces of all ships and the cargo areas of oil tankers. The terms used and the definitions are as follows:

Oil is defined as petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products other than petrochemicals.

Oily wastes means oil residues (sludge) and oily bilge-water.

Oil residues (sludge) means:

- separated sludge, which means sludge resulting from purification of fuel and lubricating oil;
- drain and leakage oil, which means oil resulting from drainages and leakages in machinery spaces; and
- exhausted oils, which means exhausted lubricating oil, hydraulic or other hydrocarbon-based liquid which are not suitable for use due to deterioration and contamination.

Oily bilge water means an oil – water mixture containing potentially sea and fresh water, fuel oil, cooling water, leakage and lubricating oil, accumulated either in designated holding tank/s or bilge wells.

Oily Mixture means a mixture of aforementioned oil components.

Thus a variety of oily mixtures might be expected in a reception facility for subsequent treatment. For the selection of adequate treatment facilities the following main characteristics will be used:

- **Dirty ballast** water may contain crude oil, black product liquid residues or white product liquid residues. Dirty ballast is usually discharged by non-SBT tankers in oil loading ports. The volumes and flow rates can be significant, but the average oil concentration is relatively low: A ship may carry around 30% of her DWT as ballast. In adverse weather conditions, this may be even higher.Flow rates for discharging to reception facilities are typically in the range of several hundred to several thousand m^3/h for large tankers. As the average oil concentration of dirty ballast which is discharged to a reception facility, a figure of 100 ppm (or 0.1 g/m^3) is assumed. Fort the reception of dirty ballast it is envisaged to use existing equipment in a number of harbors as described in Activity 1 and 2.
- Oily residues from **bilge water** are produced when the machinery spaces of a vessel are cleaned. Leaking cooling water often becomes contaminated with fuel oils and lubricant oils. Vessels in operation produce oil-contaminated bilge water to a variable extent. With the right equipment on board, dirty bilge water can be processed in a way that separates most of the oil from the water before it is discharged into the sea. If the oil content exceeds the limit, the discharge is automatically stopped (bilge alarm). However, it has been emphasized that bilge water also contains traces of detergents used in the cleaning process. When mixed, the residues of oil and detergents form a stable emulsion with another density than oil. The oil content of bilge water, as discharged to a reception facility, may considerably vary from typically 0.1 - 5%, an average oil concentration of 2% or 20 g/l is assumed. If a separator is present on board, the bilge water is treated on board and discharged with an oil concentration of max. 15 ppm. The separated oil is collected in a **slop** tank.
- Residues from crude oil **washing** systems (COW), which means that the cargo tanks, where tankers carry the oil they transport, are cleaned by means of high-pressure flushing with crude oil (‘oil to remove oil’) or crude oil plus water. This reduces the quantity of oil remaining on board after discharge. The residues from such tank washing are pumped into slop tanks and left in a reception facility in port.
- **Tank washings** are discharged in much smaller quantities than dirty ballast, the volume may vary form 1,5 - 8% of a tanker’s DWT. The oil content however is much higher than of dirty ballast. For tank washings discharged to a reception facility, an average oil concentration of 3% or 30 g/l is assumed.
- Residues of operational oil separation and filtering equipment with an automatic stopping device are collected in **slop** tanks. **Sludge** resulting from on board fuel processing (heavy fuel oil) is a highly viscous, semi-solid substance, which must be heated before it can be displaced by pumps. **Slops/oily residues/sludge** are generated on board even smaller quantities, the volume is max. 1% of a tanker’s DWT. These mixtures contain high oil and solids concentrations: 30% oil and 5% solids are assumed.

Oil - water mixtures have different characteristics depending on their density and appearance (free/emulsified).

Free oil
Oil may be present in water as free oil: small oil droplets dispersed in water by (vigorous) mixing. Usually, the higher the temperature of the crude oily waste, the easier it is to separate the oil from the water. Lighter oil fractions tend to separate more spontaneously like free oil products of light density: All oil products have a lower density than water, and therefore free oil will rise to the water surface and separate as a floating layer of oil, whereas the density of crude oil is relatively high.

Emulsified oil
Seawater acts as a natural emulsifier, increasing the viscosity of the oil-water waste, which makes it difficult to pump the waste from the barges to shore tanks for processing. Crudes, and slops often contain chemical emulsions which have been stabilized by inorganic impurities, viscosity stabilizers, etc. Tank cleaning operations also may results in an oil-water emulsion.

Emulsions are very small oil droplets, formed by high mechanical shear, as may occur by pumping an oil-water mixture. Such emulsions may be stable for some time, i.e. they do not separate quickly, but over time the particles tend to coalesce into larger oil droplets and separate. This, however, may take a (very) long time and it depends on the composition of the oily water.

Stable oil-in-water emulsions do not coalesce or separate spontaneously at all. A stable emulsion is a colloidal system of electrically charged oil droplets surrounded by an ionic environment. Stable emulsions are formed, for example, by using detergents such as industrial cleaning agents. Chemicals, such as coagulants and flocculants, are required to ‘break’ such emulsions and to separate the oil particles from the water. Water-in-oil emulsions (finely dispersed water in oil) also exist and these also require treatment with chemicals (demulsifies) to separate.

It follows therefore that free oil is the easiest component to separate, whereas emulsified oil (in particular stable emulsions) requires further treatment. Table 3 summarizes the main characteristics of waste oil.

Table 3: Typical compositions of oily wastes

	Composition				
	Oil		**Water**	**Solids**	**Type of oil to be treated**
	[ppm]	**[%]**	**[%]**	**[%]**	
Dirty ballast	100	0.01	Approx. 100	Traces	Free (mainly crude)
Bilge water untreated	20,000	2	98	Traces	Free and emulsified oil (mixtures)
Tank washings	30,000	3	97	Traces	Free and emulsified oil (mixtures)
Slops/oily residues	300,000	30	65	5	Free and emulsified oil (mixtures)

3.2 Collection of oily waste

Trucks or mobile tanks can be used for small volumes, ranging from 5 – 25 m^3 at a time. They are therefore employed for collection of bilge water, slops, sludge's and small volumes of tank washings, but not for collecting dirty ballast. Trucks are employed if they can come alongside the ship. They are obviously not suitable for ships at anchor, SBM or loading/unloading jetties not accessible by truck.

Examples of a simple mobile tank used for collecting oily wastes from ships and a vacuum truck equipped with pumps are shown on the next page.

More advanced equipment can be obtained in form of complete vacuum trucks like shown below.

Barges, equipped with holding tanks, can be used for collecting bilge water, slops, and sludge's and, depending on their size, tank washings. Holding tanks may range from roughly 10 - 1,000 m^3. Significantly larger storage capacities are unusual. Barges can be equipped with separators (described in section 3.2), so that oil-water separation takes place on board. The treated water is subsequently discharged. This option, however, is rarely applied.

More probable will be the use of a multi-tank barge for the reception of different qualities in small quantities from several vessels, stocking 10 to 100 m^3 batches of the same or similar quality in the same tank.

Fixed pipelines are appropriate for large volumes of waste, such as dirty ballast or tank washings. They can be designed to just about any required capacity, ranging from less than 10 m^3/h to several thousand m^3/h, but once the design flow rate range has been established, that determines the operating window of a pipeline. If designed for 5 m^3/h, a pipeline cannot handle 100 m^3/h and vice versa. They are usually not applied for collecting small volumes such as slops, bilge water or sludge's.
Trucks, fixed pipelines and usually also barges (as described) discharge the collected wastes to (fixed) holding tanks for further treatment.

3.2.1 Selecting a collection method

Selecting the appropriate means for collecting oily wastes in a port depends on the following factors:
- the volume of waste to be collected per ship;
- accessibility of the ships by road/quayside or only over water;
- the required flexibility of the collection facilities.

Table 4: Collection characteristics

Collection method	Volumes/flow rates	Access to ships	Flexibility
Truck	Small	By road	High
Barge	Small – medium	By water	Medium
Pipeline	Medium – large Engineered solution	Engineered solution	Low

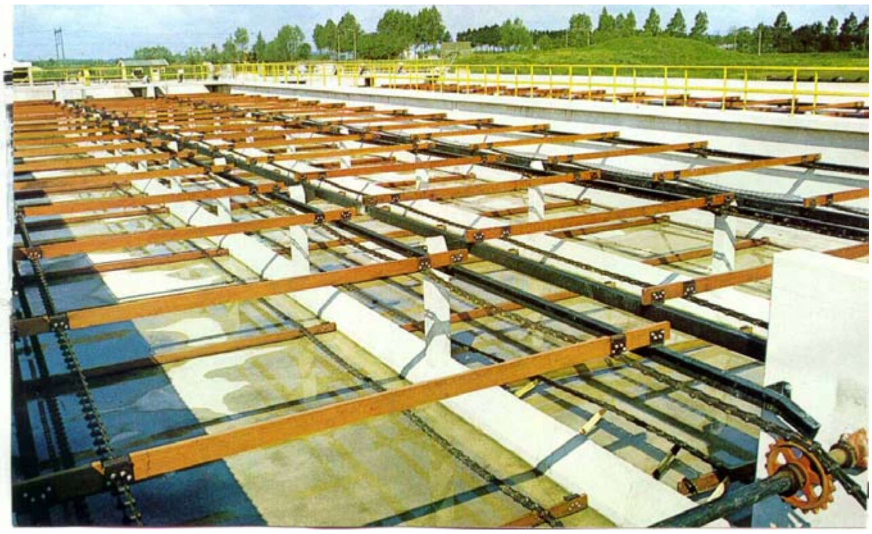
Costs are, in a way, of secondary importance: the collection means must in the first place be appropriate for a particular port. As an example: a truck is obviously much cheaper than a barge, but a truck is completely useless for collecting wastes if it does not have access to the ship (ships at anchor, SBM, jetties). A barge is capable or receiving larger volumes than a truck, but again that is irrelevant if only small volumes are delivered in a port.

3.3 Primary treatment to remove free oil

As explained in chapter 3.1, oily waste water may contain free and/or emulsified oil. Primary treatment aims at removing free oil. In this section several techniques are addressed which can be used to remove free oil. Obviously, the first separation of water, oil and solids takes place in a holding tank. Oil rises to the surface and solids settle at the tank bottom. The separation efficiency is unreliable, since filling or emptying the tank creates turbulence.

3.3.1 API separator

An API separator is a rectangular basin, mostly constructed of concrete, where the separation process takes place by gravity. By creating retention time in the basin, pollutants lighter (oil) and heavier (solids) than water are separated as floating scum (oil) and bottom sludge (sand and other solids). These are subsequently removed by a scraping device for bottom sludge and a device for floating scum removal from the surface. The most frequently used equipment for the combination of both purposes is a chain scraper mechanism. Simpler oil skimming devices also exist. API-separators are often used at refineries, oil terminals and de-ballasting facilities for large flow rates.

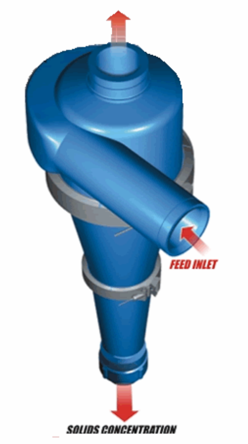


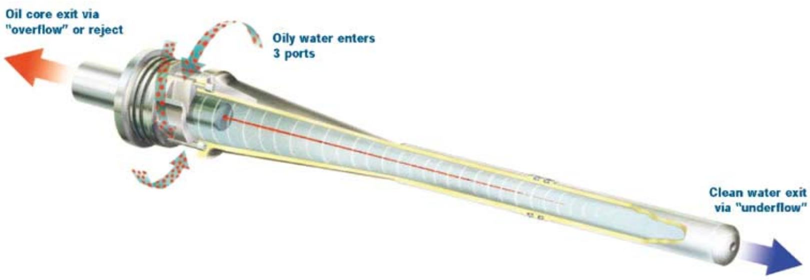
API separators	Typical unit capacities 100 – 600 m^3/h		
	Free Oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	physical	physical	Physical
Addition of chemicals	no	No	No
Removal efficiency [%]	90 - 95	0	80 – 95
Typical effluent quality (oil) [mg/l]	15 - 20	n.a.	20 – 30

3.3.2 Hydrocylone

Hydro cyclones are (enhanced gravity) separators without moving parts. The shell consists of an inverted cone with a tangentially feed inlet into the upper (larger diameter) part. The resulting spinning motion forces solids to the wall of the device and they exit from the bottom of the cone, while the cleaned liquid exits at the top. Hydro cyclones are classified by the size of the cone and will separate particles in the medium-, fine- and ultra fine-size ranges.

Hydro cyclones can be used for separation of water and solids, but also for separation of water and oil. The higher the difference is between oil and water or water and solids, the better is the separation efficiency of hydro cyclones. Typical examples (horizontal and vertical model) are shown below.





The efficiency of hydro cyclones is poor in viscous fluids with constituents of relatively low specific mass differences. Hydro cyclones are commonly applied in the oil industry (on- and offshore) for separation of solids or oil from water. The units shown in the pictures above contain a number of hydro cyclones in each vessel, to increase the treatment capacity and/or separation efficiency.

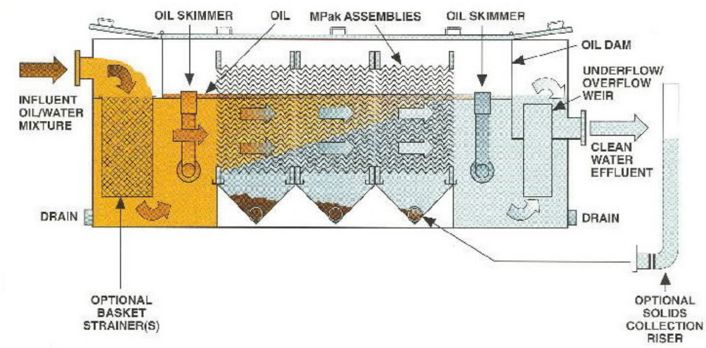
Hydro cyclones	**Typical unit capacities 1 - 50 m^3/h**		
	Free oil	Emulsified oil	Suspended Solids
Process (chemical/physical)	physical	physical	Physical
Addition of chemicals	no	no	No
Removal efficiency [%]	80 - 90	0	90 – 95
Typical effluent quality (oil) [mg/l]	20 – 30	n.a.	5 – 10

Note: Special designed hydro cyclone units can handle up to 2,000 m^3/h.

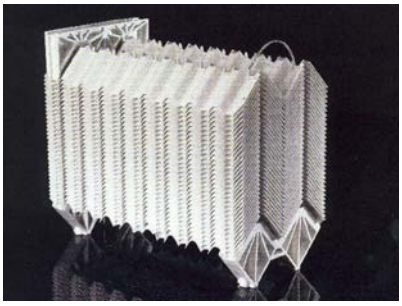
3.3.3 Coalescing plate separator

The coalescing plate separator is a rectangular steel tank which is equipped with a corrugated plate pack. These plates are mostly made of plastic or steel and increase the separation efficiency by stimulated coalescence of small oil droplets to larger droplets, which are separated more easily.

They are able to separate oil in a unit which has a much smaller footprint than an API separator designed for the same flow rate and efficiency. Solid particles are separated to the bottom of the system.



API separators, described in section 3.3.1, can be retrofitted with plate packs to increase the separation efficiency.



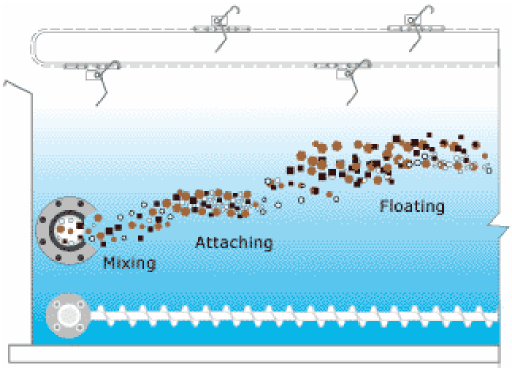
The use of a coalescing plate separator is appropriate for oily water streams with relatively low particulate impurities. The units are able to handle low to medium flow ranges. For larger flow rates, a modular design is applied i.e. several smaller units operate in parallel.

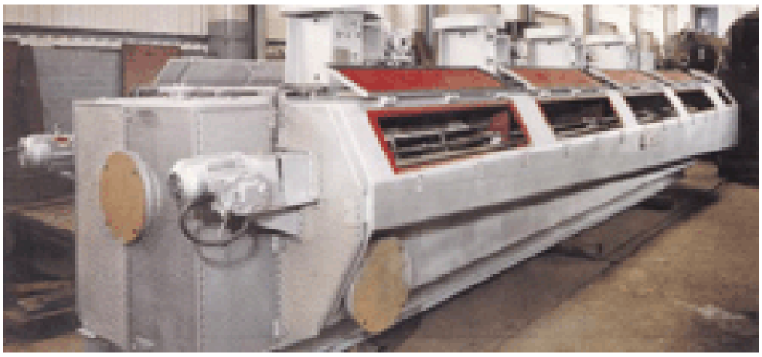
Coalescing Plate Separators	**Typical unit capacities 15 – 250 m^3/h**		
	Free oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	physical	physical	Physical
Addition of chemicals	no	No	No
Removal efficiency [%]	90 - 95	0 - 10	90 – 95
Typical effluent quality (oil) [mg/l]	10 – 15	10 – 15	5 – 10

3.3.4 Induced Air Flotation

The principle of Induced Air Flotation (or IAF) is that, by dispersing small air bubbles into the waste water which adheres to oil droplets and suspended solids, the oil and solids rise to the surface as a frothy scum where they are collected and removed by a scraper mechanism. The produced sludge has high water content (typically 96%) and needs further treatment to separate the oil and water. This is usually done in centrifuges as described further in this chapter.

An IAF is normally used without adding chemicals to the water, and is a frequently applied technology in de-ballasting stations, and are available for high flow rates. An IAF does not separate emulsified oil.





IAF units	Typical unit capacities 50 – 500 m^3/h		
	Free oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	physical	physical	physical
Addition of chemicals	no	no	no
Removal efficiency [%]	80 – 90	0	90 - 98
Typical effluent quality (oil) [mg/l]	5 – 10	n.a.	5 – 10

3.3.5 Filter type coalescer

Filter type coalescers contain cartridges of filtering material which cause small oil droplets to coalesce to larger droplets. Subsequently, the oil is separated from the water. They are also used for separation of water from oil, for instance in lubricating oil systems. A typical example containing several coalescers operated in parallel/series, are shown below. Filter type coalescers work well for free oil but have a limited effect on emulsified oil.

Filter coalescers	Typical unit capacities 5 – 500 m^3/h		
	Free oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	Physical	Physical	physical
Addition of chemicals	No	No	No
Removal efficiency [%]	95 - 98	0 - 20	0
Typical effluent quality (oil) [mg/l]	5 – 10	n.a.	n.a.

3.4 Secondary treatment to remove emulsified oil

Tank washings and bilge water will contain mechanically or chemically emulsified oil. Therefore, techniques which remove free oil only will show a poor performance with these wastes. Whereas these techniques may be applied as pretreatment, further treatment is required to obtain an effluent which can be discharged.

3.4.1 Coagulation - flocculation

A much better effluent quality can be achieved by breaking an emulsion by applying coagulation and flocculation. For that purpose chemicals are added to the oily waste water. Thus emulsified oil particles and solids form larger flocks which are subsequently separated by (usually) flotation. Common coagulants are inorganic salts such as alum, ferric chloride, ferrous sulphate, lime, sodium hydroxide or organic polymers. Depending on the type of chemical, they are commercially available as concentrated solutions, requiring dilution before adding them to the waste water, or as powder, which must be dissolved before use. Mixing chemicals with the raw waste water may take place in coagulation/flocculation tanks, inline mixers or pipe-flocculators (a plug flow type mixing device without moving parts).

3.4.2 Dissolved Air Flotation

The Dissolved Air Flotation (DAF) is a flotation system where, compared to the IAF system, the air bubbles in the water are substantially smaller. These very fine bubbles guarantee higher separation efficiency. For optimal performance preconditioning of the waste water with coagulation - floccation is almost always applied.

The air bubbles are generated by saturating a small continuous flow of clarified water with air from a small compressor at a pressure of approx. 6 bar. The pressurized air/water feed is then injected into the flotation tank and the sudden pressure drop causes the release of very fine air bubbles. They attach to the flocculated oil/solids, which then rise to the water surface in the flotation tank and form a floating layer. A scraper/skimmer removes the scum, with a typical 5% solids and oil, to the discharge hopper and the treated water is discharged.

A DAF-unit may be equipped with a plate pack (as described in section 3.3.3) to further increase the separation efficiency and hydraulic load, thereby further reducing its footprint.

DAF units	**Typical unit capacities 10 – 500 m^3/h**		
	Free oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	Chem./physical	Chem./physical	Physical
Addition of chemicals	yes	yes	Yes
Removal efficiency [%]	95 - 98	95 - 98	95 – 98
Typical effluent quality (oil) [mg/l]	5 – 10	5 -10	5 – 10

Coagulation/flocculation followed by a DAF-unit has countless applications in industrial waste water treatment.

3.4.3 Membrane filtration

Membrane filtration is a technology which has been developed in the past 2 decades for water and waste water treatment. Membrane filtration systems can be categorized in micro filtration (MF), ultra filtration (UF), nano filtration (NF) and reverse osmosis (RO). Micro filtration membranes have a relatively large pores, UF and NF separate smaller particles and RO is capable of removing dissolved matter (salts). MF and UF are applied in waste water treatment (though not very frequent) and NF is very rarely applied. RO is applied for production of drinking water or boiler feed water and unfit for waste water treatment unless extensive pre-treatment (MF and/or UF) is applied.

Membranes are manufactured of various materials, mostly polymers such as cellulose, nylon, PTFE, but membranes can also be made of ceramics. Membranes are manufactured in various configurations, such as hollow fibre, tubular or spiral wound membranes, which are fitted in membrane modules. Membranes produce a permeate (or cleaned water) and a retentate (in which the pollution is concentrated). The retentate, which may still contain 98 - 99% water, must be disposed of. Depending on the type of membranes and the composition of the waste water, the retentate of a micro-filtration or ultra-filtration unit may constitute 5 - 10% of the waste water flow rate.

Whereas membrane filtration is capable of achieving an effluent oil concentration of 5 ppm or less, it should be noted that membranes so far have not been used widely in heavy duty applications such as the treatment of oily wastewater and the development of membranes for these applications is still under research. Special chemically modified ceramic membranes for the treatment of oil-in-water emulsions might replace the present commercial system within the next five years. Membrane systems suffer from fouling problems and show a poor long term stability of water flux.

The majority of commercial plants is used onboard ships and accordingly has a low treatment capacity. Tailor-made plants for larger capacities are characterized by high investment and ever higher maintenance costs. Membranes must be replaced every 3 - 5 years.

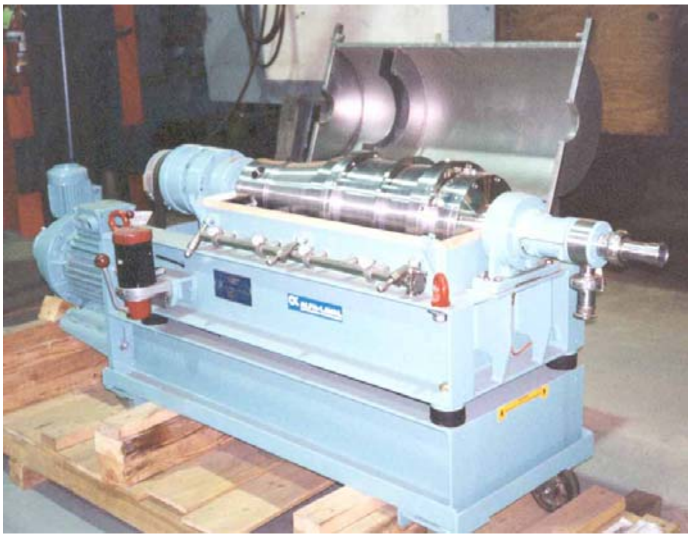
Membrane Filtration	**Typical small unit capacities 1 – 10 m³/h** **Tailor made unit capacities 10 – 50 m³/h**		
	Free oil	Emulsified Oil	Suspended Solids
Process (chemical/physical)	Chem./physical	Chem./physical	In additional pre-treatment
Addition of chemicals	yes	yes	yes
Removal efficiency [%]	95 – 99	95 - 99	95 - 98
Typical effluent quality (oil) [mg/l]	5	5	n.a.
Retentate production [% of flow]	5 – 10	5 – 10	5 – 10

3.5 Treatment of waste oil

Treatment of waste oil, slops and residues aims at reducing the water and solids content of the oil, to make it suitable for further use. Obviously, the first separation takes place in a holding tank, where water settles at the bottom and can be drained from the tank. Further separation of water and solids is generally done with centrifuges.

3.5.1 Centrifuges

Decanter centrifuges are suitable to separate mixtures between water, liquids and solids into two or three phases. The continuous decanter centrifuge is well suited for dewatering of oily sludge, although it is impossible to avoid the entrainment of a certain amount of oil into the centrate. Decanter centrifuges may be used for treating fuel oil, lube oil, bilge water and stuffing box oil, drain water de-oiling, crude oil dewatering and slop separation.



Decanter centrifuges are fed by variable-flow displacement pumps. Flocculation is carried out in-line, i.e. by direct introduction of the polymer solution into the sludge line just upstream of the centrifuge. Shallow cone decanters are used for liquid clarification, solids dewatering and classification, and three-way separation of two liquids and one solid phase. The decanter discharges all separated phases continuously. Variable feed streams can be handled by adjusting the differential speed in the system.

Decanter Centrifuges	**Typical unit capacities 5– 50 m^3/h**		
	Water from free oil	Water from emulsified oil	Suspended solids from oil
Process (chemical/physical)	physical	Chem./physical	physical
Addition of chemicals	Yes	Yes	yes
Removal efficiency [%]	60 – 90	10 - 30	80 - 90
Processed phases	Water/oil/mud	Water/oil/mud	Water/oil/mud

Another type is the disc bowl centrifuge. A sludge treatment system normally includes a heating system, feed pumps, bulk hoppers, conveyors and screen separators. Several centrifuges may be installed in parallel to increase the total treatment capacity.

Disc Bowl Centrifuges	Typical unit capacities 5 – 10 m³/h		
	Water from free oil	Water from emulsified oil	Suspended solids from oil
Process (chemical/physical)	physical	Chem./physical	physical
Addition of chemicals	Yes	yes	yes
Removal efficiency [%]	60 – 90	40 - 80	90 - 95
Processed phases	Water/oil	Water/oil	Water/oil

3.5.2 Vacuum dehydration

Water from oil is also removed by vacuum dehydration. These systems are predominantly used for oil purification. They are designed to remove free, emulsified and dissolved water, particulate, and gaseous contamination from petroleum and synthetic oils.

Since this technology is specially designed for the treatment of fuel oil with a steady feed composition it is not regarded to be applicable for the treatment of waste oil mixtures with widely varying feed compositions. Therefore no further details are evaluated.

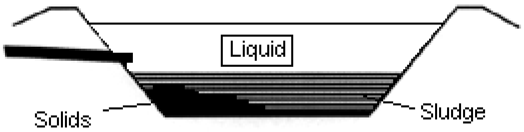
3.6 Dewatering of residual sludge

Sludge, such as tank bottoms and in particular sludge from separation processes (API separators, coalescing plate separators, flotation units, which may contain as much as 95% water) is almost always dewatered before final disposal. A number of methods are frequently applied.

3.6.1 Lagoons

Sludge may be dewatered during storage in lagoons constructed in natural earth depressions or with earthen dikes. In order to avoid environmental and public health hazards, the lagoons should be constructed with (hand) sealed, geotextile fabric placed on a clay layer. An anchor trench should be dug around the lagoons, and the edges of the fabric locked in place and approx. 0.5 m of soil be replaced to protect the cover.

Dewatering is the result of physical separation according to the specific weight and evaporation of liquids (during a longer period). Removal of free liquids from the lagoon can easily be achieved with pumping from the surface while sediments can be removed by dredging or digging. Cleaning of the lagoons (sediment removal) is required in regular intervals.



Lagoons			
	Free oil	Other liquids	Suspended Solids
Process (chemical/physical)	physical	physical	Physical
Addition of chemicals	no	no	No
Processed phases	Oil/water/mud	Oil/water/mud	Oil/water/mud
Removal efficiency [%]	Not predictable	Not predictable	Not predictable

3.6.2 Sludge drying beds

Open drying beds can be seen as 'lagoons with a drain facility'. The drain is commonly made of coarse sand underlain by coarse gravel, laid on drain collectors. Fluids are withdrawn via the drain and on the other hand evaporated from the surface layer. They are widely used in tropical areas as they have the advantage of drying as well as dewatering and require virtually no mechanical equipment. The performance and use of drying beds however is affected by a number of factors, including:

- weather conditions;
- sludge characteristics;
- land values and the proximity of residences.

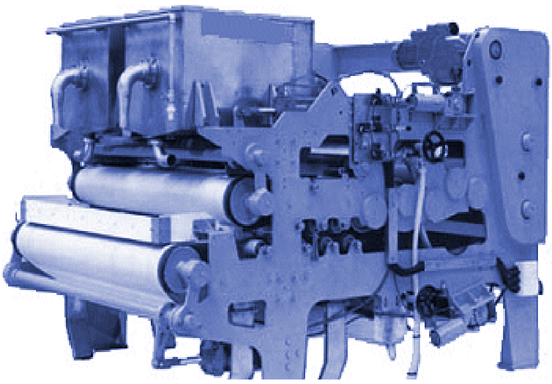
Drying beds are not particularly suitable for oily sludge's, as drying and draining are slow and the drain might be clogged with oil.

Drying Beds			
	Free oil	Other liquids	Suspended Solids
Process (chemical/physical)	physical	physical	Physical
Addition of chemicals	No	No	No
Processed phases	Mud/oily water	Mud/oily water	Mud/oily water
Removal efficiency [%]	Not predictable	Not predictable	Not predictable

3.6.3 Mechanical sludge dewatering equipment

As already described in section 3.5.1, **decanter centrifuges** are often used for dewatering of (oily) sludge's. Furthermore is filtration a frequently used method of sludge dewatering. Filtration may consist of draining through beds of sand (drying beds) or it may be 'mechanical', under pressure or under vacuum, which requires more complicated equipment. The most advanced techniques are heat drying and evaporation.

Continuously operating **belt filter presses** or batch-wise operating plate type **filter presses** use filter fabrics for separation of liquids and solids. These fabrics are in connection with oil contaminated sludge subject to severe clogging which only can be avoided by addition of so called conditioning material. Conditioning will add approx. 100 – 200 % of solids to the original sludge stream.



Another frequently used filter technique is the **vacuum filter**.

A vacuum filter consists of a hollow cylinder covered with a filtering medium made of cloth, plastic or stainless steel. As the cylinder revolves, a vacuum is applied to a section of the drum immersed in the wet sludge. By increasing the vacuum, water is drawn through the filtering medium, leaving the sludge in the form of a cake that is discharged after one revolution.

All these filtering techniques have the severe disadvantage that substantial quantities of conditioning chemicals have to be added and the filter cloth becomes regularly clogged by oil. This result in high operating and maintenance costs and therefore these techniques are not evaluated in further detail.

Heat Drying reduces the moisture content to about 10%, which is much less than it can be attained on sludge drying beds, centrifuges or by vacuum filtration. Types of equipment are:

- rotary kilns;
- flash dryers.

Since heat drying is very expensive in terms of capital investment and operational costs it is not regarded a feasible technology for treatment and disposal of ship generated liquid waste. Heat drying of wastes before final disposal is not widely practiced, even in industrialized countries.

3.7 Determining factors for selecting a treatment technology

3.7.1 Selection criteria

In this section possible process modification alternatives of measures at the source are evaluated. We have applied a structured approach, taking into account several relevant criteria:

A. proven technology (a technology commonly found for similar applications);
B. achievable effluent quality;
C. required maintenance (should be low);
D. utilities consumption (should be low);
E. space requirements (should be low);
F. investment costs (should be low).

The aspect of achievable effluent will be differentiated to the type of oil a particular technology removes. As an example: an API separator works well for free oil (for which it can be applied), but not for emulsified oil (for which it therefore cannot be applied). It is therefore important to identify which type of treatment technology works for the types of waste water as listed above. The results of the identification are summarized in following tables. It must be emphasized that specific local limiting conditions are not taken into account.

3.7.2 Selection of technologies

Table 5 summarizes the characteristics of the types of treatment technology as discussed in the previous sections.

Table 5: Treatment adequacy per oil component

	Treatment Result on			
Technology	Free Oil	Mechanically formed Emulsions	Chemical stable emulsions oil in water	Chemical stable emulsions water in oil + suspended solids
API Separator	++	-	- -	- -
Hydro cyclone	+	-	- -	- -
Plate Coalescer	++	++	-	-
Filter coalescer	+	++	-	-
IAF	++	+	-	-
Chem.Treatment + IAF	++	++	+	+
DAF	++	+	+/-	+/-
Chem.Treatment + DAF	++	++	++	++
Membrane Filtration	++	++	++	+
Decanter Centrifuge (+ chemicals)	+	+	++	++
Disc Bowl Centrifuge (+ chemicals)	+	+	++	++

-.-: does not meet the objectives
-: meets the minimum objectives
+: meets the objectives
++: exceeds the objectives

Technologies with a '+ and '++' characterization are evaluated in the following tables. Furthermore a number of sludge treatment techniques, as described in section 3.6 and later in section 6, are evaluated too.

Please note that '++' on proven technology might be interpreted as 'many references, commonly applied' and '++' on low effluent oil content means far below the accepted effluent oil concentration for discharge.

Table 6: Technologies for free oil removal

	Quality Criteria					
Technology for free oil removal (ballast)	Proven technology.	Low effluent Oil content	Low maintenance	Low utilities consumption	Low space requirement	Low Investment costs
API separator	++	-	++	+	- -	-
Hydro cyclone	-	-	++	++	++	+
Plate Coalescer	+	+	+	+	+	+
Filter Coalescer	+	+	-	+	+	+
IAF	+	++	-	-	-	-
IAF incl. fore. Treatment	+	++	+	- -	-	-
DAF	+	++	-	-	-	-
DAF incl. fore. Treatment	+	++	+	- -	-	-
Membrane Filtration	- -	++	- -	-	+	- -
Decanter centrifuge	- -	-	-	-	-	-
Disc Bowl centrifuge	- -	+	-	-	-	-

Table 7: Technologies for emulsified removal

	Quality Criteria					
Technology for emulsified oil removal (tank wash, bilge)	Proven technology	Low effluent Oil content	Low maintenance.	Low utilities consumption.	Low space requirement	Low Investment costs
Plate Coalescer	+	-	++	++	+	+
Filter Coalescer	+	-	+	++	+	+
IAF	+	-	+	++	+	-
IAF incl. fore. treatment	++	+	+	-	+	-
DAF	+	+	+	-	+	-
DAF incl. fore. treatment	++	++	+	-	+	-
Membrane Filtration	-	++	-	+	+	- -
Decanter centrifuge	- -	-	-	-	-	-
Disc Bowl centrifuge	- -	-	-	-	-	-

Table 8: Technologies for water removal from oil

	Quality Criteria					
Technology for water removal from oil (waste oil, slop)	Proven technology	Low effluent water cont.	Low maintenance	Low utilities consumption	Low space requirement	Low Investment costs
Decanter Centrifuge	++	-	+	+	+	+
Disc Bowl Centrifuge	++	+	-	+	+	-

Table 9: Technologies for sludge de-watering

	Quality Criteria					
Technology for sludge de-watering (fuel processing, liquid waste treatment plant)	Proven technology.	Low effluent water cont.	Low maintenance	Low utilities consumption	Low space requirement	Low Investment costs
Decanter Centrifuge	++	+	-	+	+	-
Disc Bowl centrifuge	+	+	-	+	+	-
IAF incl. fore. treatment	+	-	-	-	-	-
DAF incl. chemical treatment	++	-	-	-	-	+
Belt Filter Press	- -	+	- -	- -	+	-
Plate Filter Press	- -	+	- -	- -	-	-
Vacuum Filter	- -	+	- -	-	+	-
Rotary Kiln	+	++	-	- -	-	- -
Flash Dryers	-	++	- -	- -	-	- -
Lagoon	+	++	+	++	++	-
Sludge Drying Bed	+	+	+	++	++	-

3.8 Assessment of applicable techniques

The assessment of a potential liquid treatment technique is based upon the criteria (A to F) as afore described in paragraph 3.7.2 and the weighting factors as defined below. The weighting factors are based on expert judgment resulting from the experience with similar projects.

The score per criteria used in the assessment, divided in 4 levels, is as follows:

-2 inadequate
-1 poor
+1 good
+2 very good

The total score was counted and multiplied with the following weighting factors:

	Criteria	Weighting factor [%]
A	Proven technology	30
B	Low effluent oil/water content	20
C	Low maintenance	10
D	Low utilities consumption	10
E	Low space requirement	10
F	Low investment costs	20
	Total	**100**

The total score is determined using the equation:

$$\text{Total}\quad \text{score} = \sum_{i=A}^{F} score_i \times weighing\ factor_i$$

The results are presented in Table 10.

Table 10: Assessment of liquid ship waste treatment technologies

Table	Technique / weighing factors	A 30	B 20	C 10	D 10	E 10	F 20	Total Score	Ranking
6	API separator	2	-1	2	1	-2	-1	50	**3**
	Hydrocyclone	-1	-1	2	2	2	1	10	**7**
	Plate Coalescer	1	1	1	1	1	1	90	**1**
	Filter Coalescer	1	1	-1	1	1	1	70	**2**
	IAF	1	2	-1	-1	-1	-1	30	**5**
	IAF incl. chem. treatm.	1	2	1	-2	-1	-1	40	**4**
	DAF	1	2	-1	-1	-1	-1	30	**5**
	DAF incl. chem. treatm.	1	2	-1	-2	-1	-1	20	**6**
	Membrane Filtration	-2	2	-2	-1	1	-2	-90	**9**
	Decanter centrifuge	-2	-1	-1	-1	-1	-1	-120	**10**
	Dsic Bowl centrifuge	-2	1	-1	-1	-1	-1	-80	**8**
7	Plate Coalescer	1	-1	2	2	1	1	70	**2**
	Filter type coalescer	1	-1	1	2	1	1	60	**3**
	IAF	1	-1	1	2	1	-1	20	**5**
	IAF incl. chem. treatm.	2	1	1	-1	1	-1	60	**3**
	DAF	1	1	1	-1	1	-1	30	**4**
	DAF incl. chem. treatm.	2	2	1	-1	1	-1	80	**1**
	Membrane Filtration	-1	2	-1	1	1	-2	-30	**6**
	Decanter centrifuge	-2	-1	-1	-1	-1	-1	-120	**7**
	Dsic Bowl centrifuge	-2	-1	-1	-1	-1	-1	-120	**7**
8	Decanter Centrifuge	2	-1	1	1	1	1	80	**1**
	Disc Bowl Centrifuge	2	1	-1	1	1	-1	60	**2**
9	Decanter Centrifuge	2	1	-1	1	1	-1	60	**2**
	Disc Bowl centrifuge	1	1	-1	1	1	-1	30	**3**
	IAF incl. chem. treatm.	1	-1	-1	-1	-1	-1	-30	**5**
	DAF incl. chem. treatm.	2	-1	-1	-1	-1	-1	0	**4**
	Belt Filter Press	-2	1	-2	-2	1	-1	-100	**8**
	Plate Filter Press	-2	1	-2	-2	-1	-1	-100	**8**
	Vacuum Filter	-2	1	-2	-1	1	-1	-90	**7**
	Rotary Kiln	1	2	-1	-2	-1	-2	0	**4**
	Flash Dryers	-1	2	-2	-2	-1	-2	-70	**6**
	Lagoon	1	2	1	2	2	-1	80	**1**
	Sludge Drying Bed	1	1	1	2	2	-1	60	**2**

Based upon the results as presented in table 10 the following techniques were assessed to be suitable for reception and treatment facilities for oily wastes from ships.

Table 11: Assessment results

Source	Treatment	Technology
Ballast water	Free oil removal	**Plate Coalescer**
Tank washings, Bilge water	Emulsified oil removal	**DAF + Flocculation**
Waste oil, slops	Water removal from oil	**Decanter centrifuge**
Sludge processing, buffer tanks, sludge from treatment plant	Water removal from sludge	**Lagoons**

4 Recycling and final disposal of waste

4.1 Types of waste for recycling an final disposal

Treatment of oily wastes and garbage from ships eventually lead to a limited number of residues which may be recycled or – if recycling is not an option - for which a final disposal option must be found.

Oil
Recovered oil can be blended with (bunker) fuel or for use in ships and boiler plants. It can be used as low grade fuel and burned in asphalt plants, cement and lime kilns or waste incinerators, thereby using its calorific value. Recovered oil can also be re-refined.

Sludge
Sludge from the liquid waste streams can be dried prior to final disposal in order to reduce volume and to generate a waste which is easy to handle. This drying may consist of a number of steps:

- Dewatering by natural evaporation;
- Mechanical dewatering;
- Thermal drying;
- Incineration.

Chapter 3.6 describes several possibilities for the dewatering of sludge that is generated by ship waste treatment. Whereas the dewatered sludge will have a solid or semi-solid consistency, it can still contain water between 50% and 80% of it's entire mass. There are technical options available to further reduce the water content of (de-watered) sludge, i.e. drying and incineration. These options are discussed in chapter 4.3 below.

Solid garbage
Non separated solid garbage can be incinerated to gain a substantial volume reduction or it can be sent to a landfill too. Separated fractions of solid garbage can be re-routed into recycling processes. The most favorable option for the final disposal of garbage is storage in a controlled landfill.

4.2 Recycling options

4.2.1 Garbage

Recycling is the use of waste material as a source raw material. Recyclable materials include for example, aluminum cans, scrap metals, plastics, glass and paper. Activity 1 reports that in all ports garbage from ships is brought to a landfill, and no further information is presented on recycling schemes for garbage. An overview of the quantities of garbage from ships in each port, as reported in Activity 1, is presented in Annex B. It follows that food waste constitutes the major part of the total volume of garbage to be received.

A particular difficulty with food wastes may be that importing these wastes from ships is sometimes officially prohibited by regulations on public health or by veterinary regulations. The report on Activity 1 does not provide information on this issue.

The following situation may then occur:

- food waste cannot be received according to the applicable public health or veterinary regulations;
- if, nevertheless, food wastes are received from ships, incineration is the only technology that is guaranteed to eliminate any health or veterinary risk;
- everyday practice is that food wastes are received (segregated or mixed with other garbage) and are brought to a landfill.

All types of garbage from ships are expected in such quantities that there is no justification for proposing waste separation and recycling options for garbage from ships only. For any port, this is a feasible option only if a separation and recycling facilities for garbage from land based (municipal) sources already exists. Since this does not appear to be the case, there is no point in elaborating on options for separating and recycling garbage from ships. Nevertheless, in Annex C some information is presented on separation methods, as background reading material on this issue.

4.2.2 Oil

Waste oil can be reused for various purposes, depending on the composition and quality requirements. The reports on Activity 1 and 2 outlined several options:

- mixing with bunker oil;
- use a secondary fuel in cement kilns, boiler houses and so forth;
- re-refining.

With regard to the final disposal option for oil, the situation as described in the reports in Activity 1 and 2 provides useful information. In some countries, a scheme for oil collection and processing of waste oils exists, e.g. in Slovenia. In several other ports, a refinery may be able to accept the recovered oil, like in Rijeka. Whenever possible, final disposal of waste oil from ships should be tied into these existing routes for treatment and final disposal, since this will be by far the option with the lowest cost.

In Annex D a rough calculation is made of the volume of (potentially) recoverable oil, based on the average composition of oily wastes. It then quickly follows that, in particular for those ports where a disposal route for oil has not been identified yet, the volumes are small and these do not justify setting up a dedicated treatment plant (such as a distillation unit). Our approach to this issue, as regards the design of the treatment facilities in each port is further elaborated in chapter 5.1.

4.3 Final treatment and disposal

4.3.1 Drying

Before thermal drying may become effective mechanical dewatering should be applied. A number of dewatering techniques are already presented in the section 3.6 about treatment of sludge (vacuum filters, filter presses, lagoons and sludge drying beds). For sludge treatment by heat drying and incineration the water content should be < 50%.

Thermal drying reduces the water content of the sludge to very low levels. Incineration not only totally eliminates the water content in the sludge, but also involves combustion of the organic matter contained in the sludge. Ash, consisting of the inorganic non-combustible fraction of the sludge, remains and must be disposed of.

Incineration obviously includes a drying phase, but since it uses the calorific value of the organic substance of the sludge, it always requires less energy than a heat drying. For this reason heat drying is only worth considering if the end product can be reclaimed and marketed within an industrial manufacturing process (or if disposal of the sludge is so expensive that the costs of drying are compensated by the reduction in costs for disposal, but this is rarely the case). If there is no market for such products direct disposal or incineration are the most feasible options for sludge removal.

Drying installations have been briefly addressed in chapter 3.6.3 as an alternative for mechanical sludge dewatering. Such systems can be designed for batch or for continuous operation. One of the mainly used technical systems is fluid bed systems, as shown below. Adequate evaporation capacity must be provided to meet the maximum expected demand under peak loading conditions. The evaporation rate is the most critical design criteria for sizing a thermal drying system.

Another thermal sludge drying technology is a rotary drum dryer as shown in the next photograph.

The standard dryer sizes are based on evaporation rate capacities of one or several metric tons per hour. Drying results in a volume reduction of the waste to be disposed of, but has no other benefits.

4.3.2 Incinerators

To reduce waste volume in a controlled burning process, incinerators are commonly applied both as batch type or continuous operation. Incinerators are commercially available in a wide range of capacities, from approx. 50 kg/day to several ten tons per hour, or even larger. Depending on the size of the incineration plant, systems may be added such as heat recovery, power generation and flue gas treatment. Incinerators should preferably used for continuous operation. Burning waste at very high temperatures destroys harmful chemical compounds, such as PCB's. Ash and slags are disposed of in a landfill. Several examples of incinerators are shown below, from very small to medium capacities. Much larger facilities also exist.

Small incinerators are not equipped with flue gas treatment and simply emit smoke through a short stack. Large plants require extensive flue gas treatment, for which a variety of techniques are combined such as scrubbers, electrostatic filters, activated carbon filters and DeNOx. Flue gas treatment removes a variety of pollutants in the flue gas. It should be noted, however, that such large incineration plants are extremely expensive (several hundreds of million Euros) and approximately 30 - 50% of the total investment goes into flue gas treatment.




4.3.3 Landfill

Sludge disposal in a landfill is the most commonly used option for dewatered liquid waste streams. This option of direct disposal can be applied to sludge with a solid consistency. Liquid waste should not be disposed of in a landfill.

Although source reduction, reuse, and incineration can reduce the volume of waste to be disposed of, landfills are in many cases the final disposal option.

Modern controlled landfills are well-engineered facilities, which include:

- a groundwater monitoring system;
- impervious layer (geo-textile) to prevent leach ate entering ground and groundwater;
- drainage system and leach ate treatment;
- gas extraction system;
- top cover of sections which are filled up.

On the other end of the scale are uncontrolled dumping sites, used without any supervision or technical facilities preventing ground and groundwater pollution.

4.4 Determining factors for selecting final disposal options

The options described in this chapter are assessed using the following criteria:

A. proven technology (a technology commonly found for similar applications);
B. environmental impact;
C. required maintenance (should be low);
D. utilities consumption (should be low);
E. space requirements (should be low);
F. investment costs (should be low).

Table 12: Technologies for solid garbage removal

	Quality Criteria					
Technologies for solid garbage removal	Proven technology	Environmental impact	Low maintenance	Low utilities consumption	Low space Requirement	Low Investment costs
Drying	-	+	--	--	+	--
Incineration	++	+	--	-	+	--
Uncontrolled landfill	++	--	++	++	-	++
Controlled landfill	++	+	+	+	-	+

Legend
-.-: does not meet the objectives
-: meets the minimum objectives
+: meets the objectives
++:exceeds the objectives

When the multi-criteria analysis is applied as described in chapter 3.8, the results are as follows.

The score per criterion used in the assessment, divided in 4 levels, is as follows:

-2 Inadequate
-1 Poor
+1 Good
+2 very good

The total score was counted and multiplied with the following weighting factors:

	Criteria	Weighting factor [%]
A	Proven technology	10
B	Environmental impact	30
C	Low maintenance	10
D	Low utilities consumption	10
E	Low space requirement	10
F	Low investment costs	30
	Total	**100**

Table 13: Assessment results for technologies for solid waste garbage removal

Table	Technique / weighing factors	A 10	B 30	C 10	D 10	E 10	F 30	Total Score	Ranking
12	Drying	-1	1	-2	-2	1	-2	-80	**4**
	Incineration	2	1	-2	-1	1	-2	-40	**3**
	Uncontrolled landfill	2	-2	2	2	-1	2	60	**2**
	Controlled landfill	2	1	1	1	-1	1	100	**1**

A controlled landfill emerges as the preferred option; an uncontrolled landfill comes in the second place. Tebodin has included this option in the evaluation, to demonstrate the effect of the weighting factors: an uncontrolled landfill is cheap, does hardly require maintenance or utilities, but it has serious environmental effects. To avoid misunderstanding: Tebodin does not recommend uncontrolled land filling whatsoever.

It is obvious that incineration is expensive and virtually non-existent in countries participating in this study. The report on Activity 1 clearly describes that in all ports garbage is brought to a landfill and this is the solution with by far the lowest cost. Wherever appropriate and possible, uncontrolled landfills should be upgraded to controlled landfills to comply with environmental standards. We therefore will follow the existing practices in ports as described in the report on Activity 1.

5 Proposed facilities

5.1 General considerations

Before assessing which facilities are appropriate for the individual ports in every country, a number of general considerations apply.

Adequacy of existing facilities
During the Activities 1 and 2, information was collected regarding the existing facilities in each port, and an assessment was made whether these facilities are adequate or not. We will adhere to these assessments, which have been summarized in chapter 2.

Waste volumes and operation of facilities for oily waste
The Activities 1 and 2 have resulted in an estimated volume of various types of waste in each port. These results are summarized in the tables in Annex A. The reception capacity is determined by the maximum volumes of waste delivered by a ship, and an assumption regarding the number of ships which simultaneously deliver wastes. The treatment capacity, however, is determined by the average waste flow. To that end, average daily volumes of oily waste have been calculated, based on treatment during week days, i.e. 250 days per year, as well as an average flow rate per hour, based on an 8 hour per day operation of the treatment facilities. The results of these calculations are presented in Annex E. With regard to the conceptual designs, as proposed in the reports on Activity 1 and 2 for various ports, it can be concluded that:

1. the proposed holding capacity for most ports is generally sufficient for a week of average waste delivery and also sufficient to accommodate the maximum expected volume per ship;
2. the proposed treatment capacity significantly exceeds the average daily flow rate and are generally sufficient to process the maximum volume, which can be stored in the holding tank(s) in one day;
3. the necessary measures of acceptance (to avoid unvanquished mixing of oily waste streams) should be dealt with in the waste management planning.

Tebodin supports the recommendations as made in the reports of Activity 1 and 2. In particular, with respect to the item of treatment capacity, the following remarks are made:

- The holding tank will be used to separate the bulk of free oil. This requires, however, that the contents of a (nearly full) holding tank must be allowed to settle. Subsequently the oil will be transferred to an oil storage tank and the oily water is processed.
- Processing takes place in a relatively short period of time, to avoid that ships cannot deliver waste (undue delay). It is therefore appropriate to have a safe margin in the treatment capacity.
- The proposed treatment capacities for most ports are around 5 - 10 m^3/h. For many types of treatment technology, these capacities are already achieved in small - if not the smallest - model commercially available. Treatment capacities of 1 - 2 m^3/h are in many cases pilot plant models, or just above that, and we do not recommend installing such very small units.

Final disposal of oil

For several ports (refer to section 2.1) reception and treatment facilities for oily wastes are recommended, but a final disposal option for oil is not identified, and we presume that this has not been investigated in detail during Activity 1 and 2. We would like to stress that a final disposal option for recovered oil is a prerequisite for operating treatment facilities and this issue must be dealt with. If an outlet for oil cannot be found, operation of the treatment facility will come to a standstill when the oil holding tank is full, waste oil may be discharged into the environment, the collection services to the ships may deteriorate and so forth.

For several other ports (again refer to section 2.1), where very limited volumes of waste are anticipated only limited collection services are recommended without further specification what to do with the oily waste, other than that it should be disposed to an approved facility. Such a facility apparently does not exist yet in these ports. We understand the rationale, but we would also like to point out the underlying dilemmas;

- Providing the collection service to the ships may be relatively easy, but subsequent disposal (even if it is only 100 m^3 per year) may very quickly become an operation which is not environmentally sound. Oily waste may be collected for a fee, but subsequently discharged or dumped without cost and without any regard to the environmental consequences.
- the principal decision can also be made not to provide the collection service to the ships, and to inform ships accordingly. For better, this may lead to ships delivering their waste in the previous port of call, or keeping the waste on board until the next port of call where facilities are available and this overall result is better than accepting wastes without any possibility of treatment. For worse, it may lead to ships discharging at sea.

Reception and treatment of garbage

In our recommendations, we will follow the existing practice of garbage disposal, insofar described for the various ports in the report on Activity 1.

Impact of local conditions

When describing and assessing various options for treatment and final disposal in chapters 3 and 4, specific local conditions were not taken into account, and from a technological point there is no reason to do so. While it is clear that any facility (wherever its location) must be operated and maintained appropriately by properly trained operators, there are no specific local conditions which would lead to selection of different technologies in different ports and countries. In other words, as an example, a Dissolved Air Flotation Unit will work everywhere when properly operated.

However, local conditions do have an impact on the design of facilities. This relates to the presence or absence of facilities, equipment and options for disposal of processed wastes and this is further elaborated in chapter 5.2 and 5.3, which address typical facilities.

Collection of waste

The reports on Activity 1 and 2 address the required needs to collect wastes in ports, such as road tankers or barges. In chapter 5.2, typical treatment facilities are addressed and cost indications are provided. However, we have assumed that the collection of various types of wastes does not require investments in collection equipment, but that the collection is arranged through local private contractors which may already use their (for example) trucks for other purposes.

5.2 Typical facilities for oily waste

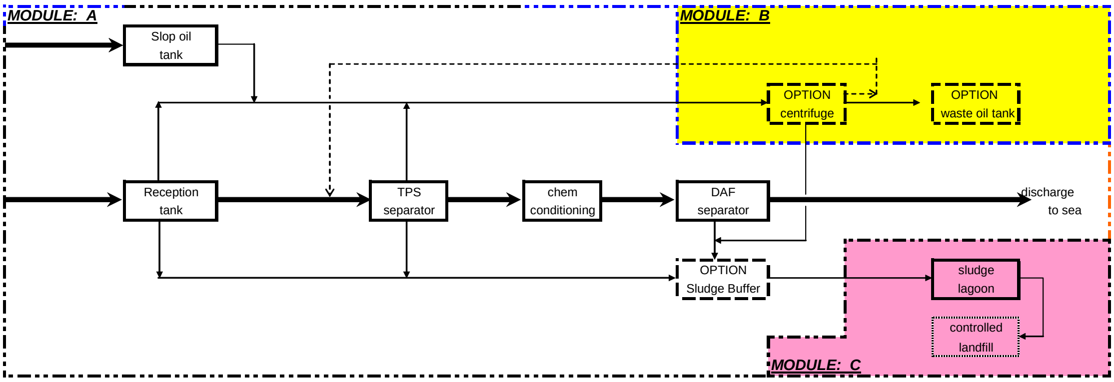
5.2.1 Description

When reviewing the proposed facilities for oily waste, as described in chapter 2.1, it appears that for several ports the requirements are very similar as regards the holding capacity and the treatment capacity. Chapter 3 leads to clear conclusions which treatment options are applicable, taking into account the selection criteria which have been described.

Therefore, we will describe in this section typical facilities which can be applied in a number of ports. In subsequent sections 5.3 – 5.12, countries and ports will be addressed individually. A typical reception and treatment facilities comprises three elementary building blocks:

- Module A: oily water reception and treatment + storage of recovered oil;
- Module B: oily residues treatment;
- Module C: sludge dewatering.

Modules A be required in any case where a port reception and treatment facility is established, Modules B and C are optional, as explained below. A simplified diagram is shown below with more detailed information in Annex F.



Module A: oily water treatment

Oily wastes with high water content (bilge water, tank washings) are transferred to a holding tank, equipped with a skimmer to remove the bulk of free oil. After sufficient residence time, the water fraction is withdrawn and pumped to a plate coalescer (tilted plate separator or TPS) to remove the remaining free oil. In some ports an API separator already exists. If that is the case, it may be used to replace the TPS, but this can be recommended only after investigating the equipment to determine if it is really fit for purpose. For now, we have assumed that a new TPS will be required.

The next step is coagulation-flocculation. Metering pumps add the required chemicals (primarily sodium hydroxide and an anionic polymer to the waste water. The effluent is then pumped into a DAF-unit, where all the flocculated oil and solids are separated.

A waste oil holding tank is provided for collecting the free oil separated in the holding tank and the TPS. Also slops and other oily residues (with high oil content) are pumped into this tank. Water that settles in this tank is intermittently drained and led to the TPS. A sludge tank is provided for holding the sludge's collected in the oil/water separator and the DAF unit. The treated effluent (typically less than 10 ppm oil) can be discharged to a sewer or the sea.

Module B: slop oil treatment
Module B should be considered as optional. The waste oil may be required to meet specifications regarding water and solids concentrations for further use. To that end, a centrifuge is applied. Water which is separated (3-phase decanter) will be re-routed to the TPS; the solids will be transferred to the sludge buffer tank and ultimately stored in a landfill. The oil, free of solids and water is stored in a buffer tank ready for further use.

As long as there are no specific quality requirements for the waste oil, there is no point in providing a centrifuge for oil treatment. Refineries - and for example also oil fired power plants - have systems in place to deal with waste oil and oily sludge's.

In ports with a refinery, we have assumed that the refinery is willing to accept the waste oil that comes out of Module A, and that Module B is not required. In ports without a refinery, another disposal route must be found for oily residues, such as a local industry which may be interested to use the oil as a second grade fuel in its boiler house. Again, module B should only be built if the need for it has been firmly established, and this can be done only after investigating locally how the oil can be disposed of. If eventually it appears that the oil cannot be used by anyone, it may then be required to install a dedicated incinerator for waste.

Module C: residual sludge treatment
Dewatering of sludge, separated in the modules A and B, has to be applied before final disposal can take place. The suggested disposal route for sludge consists of sludge dewatering in drying beds or in a lagoon followed by a controlled landfill for final disposal. From the drying bed/lagoon the remaining solids are excavated (e.g. once or twice a year) and transported to an existing landfill.

5.2.2 Investment costs for typical facilities for oily waste

For the estimation of investment costs, the assumptions as described in section 5.2 formed the starting point. Typical plant capacities for Module A were identified to be:

- A-I: Flow capacity 10 m^3/h with a reception/holding tank of 70 m^3;
- A-II: Flow capacity 20 m^3/h with a reception/holding tank of 150 m^3;
- A-III: Flow capacity 50 m^3/h with a reception/holding tank of 500 m^3.

The typical plant 'I' fits to Vlore, Saranda, Shengjon and Rijeka-Rasa. The typical plant 'II' fits to Durres and 'III' fits to Ploce. For Omisalj specific recommendations apply, which will be addressed in the country specific sections further in this chapter.

For the modules A and B cost estimates are prepared as follows:

- Costs of main equipment were determined;
- Factors were used to add costs for civil works, process control, a building and so forth to arrive at the total costs of the facility. It is assumed that tanks are located in open air, whereas the treatment equipment will be located in side a small and simple building.

For module C merely a provisional sum was assumed since these facilities can be constructed[3] with local skill and labor.

It should be noted that the resulting cost estimates must be used with caution, and serve as an indication only. More accurate estimates can be prepared after completion of relative designs, including an inspection of the local situation. Specific local circumstances may have a significant impact on the total cost of building a reception and treatment facility. Examples are:

- Costs of power supply to the facility may be significantly affected by the location where the facility will be built;
- The same applies to costs for sewers, access roads, and so forth.

Table 14: Indicative investment costs for reception tanks

		Order of Investment [x € 1,000]			
Plant		Module A	Module B	Module C	Total
I	Reception Tank 70 m^3 Flow Capacity 10 m^3/h	1,100	250	150	1,500
II	Reception Tank 150 m^3 Flow Capacity 20 m^3/h	1,400	250	150	1,800
III	Reception Tank 500 m^3 Flow Capacity 50 m^3/h	1,700	350	500	2,550

5.2.3 Basic facilities for ports with limited collection services

For a number of ports, limited collection services were recommended. The wastes should then be discharged to a temporary storage facility or a facility for treatment and final disposal. Typical facilities for treatment and final disposal have been discussed in the chapters 5.2.1 and 5.2.2.

A temporary storage facility for oily waste can be as simple as a fenced storage yard for drums, IBC's or tank containers (as an alternative for fixed tanks), accessible by truck. The basic requirements, from an environmental point of view, should ensure that the oily waste cannot disperse into the environment. Therefore, drums/containers must be in good condition. i.e. not leaking or rusting, closed with a hatch or lid to prevent rain water entering the containers and fit to withstand local extreme weather conditions (temperature, wind, rain). To that end, a shelter may prove useful.

[3] Sludge drying beds are commonly made of a coarse sand under drain with side walls of low earth embankments, concrete walls or wooden planks. The drains, which are laid under the gravel, are usually made of cement or of stoneware when the sludge is aggressive. Lagoons are excavated ponds with subsoil insulation.

Since these facilities are very simple, we have not made a design of them. We again would like to point out that a temporary storage is not really recommendable unless a disposal option for the oil is found and it may also be considered not to collect the oily wastes in these ports.

5.3 Typical facilities for garbage

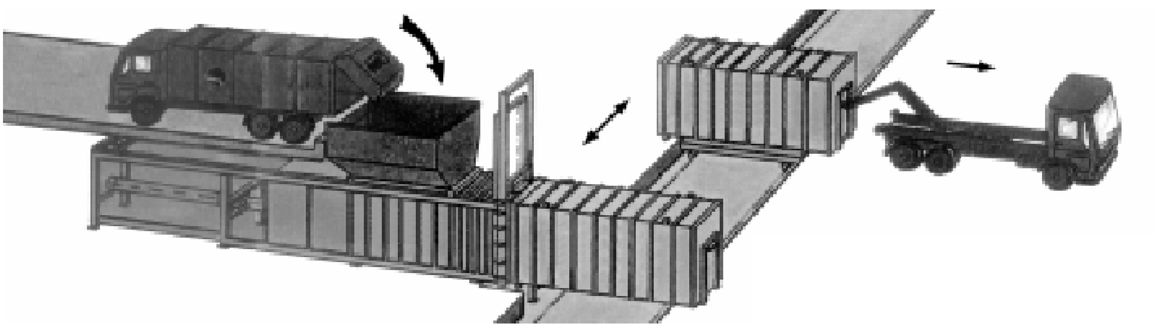
With respect to garbage, the following conclusions are presented in the report of Activity 1: adequate facilities are present in all port, with the exception of:

- o Saranda, where additional receptacles are recommended;
- o Plomin, where the separation of food waste is recommended.

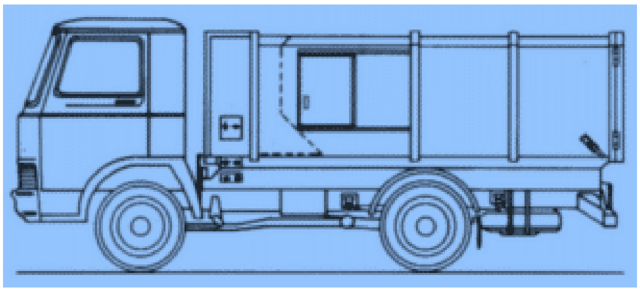
With respect to receptacles, we presume that it is not necessary to provide a typical design.

For the ports where - according to Activity 1 on a pilot basis – a basic garbage transfer station could be established, the following remarks apply. The report on Activity 1 does not provide clear information what is done with municipal garbage. Some sort of segregation may or may exist. However, since the volumes of garbage from ships will for the biggest part consists of food wastes (as estimated in Activity 1), we conclude that there is not much scope for waste separation for recycling purposes. For now, we assume that the primary objective of a garbage transfer station is to improve logistics, such as efficient use of collection vehicles and minimization of transport movements in a (congested) port area.

Depending on the local needs, garbage transfer stations can be designed with various levels of technical sophistication. An example is shown below.



Other options are self compacting trucks or containers.



A field inspection must be carried out to assess the local situation and to determine which option is appropriate.

5.4 Recommendations Albania

Oily waste

Ports where reception and treatment facilities should be established, according to Activity 1 and 2, are highlighted in grey.

Port	Ballast (m^3/year)	Tank washings (m^3/year)	Bilge water (m^3/year)	Sludge, residues (m^3/year)
Durres	0	0	4.233	2.062
Vlore	0	0	959	444
Saranda	0	0	90	150
Shengjin	0	0	784	310

The proposed typical facilities for these ports regarding oily waste are summarized in the table below. Reference is made to chapter 5.2 and Annex E for details regarding the proposed facility.

	Treatment facility	Cost estimate (x€ 1,000)	Remarks/assumptions
Vlore	Tank 20 m^3l	150	Reception tank only, disposal by Licensee or treatment in refinery.
Saranda	Tank 20 m^3	150	Reception tank only, disposal by Licensee or treatment in refinery.
Shengjin	Tank 20 m^3	150	Reception tank only, disposal by Licensee or treatment in refinery.

Module A: storage of slops/residues + oily water storage and treatment

Garbage

No additional facilities are required regard to garbage.

5.5 Recommendations Croatia

Oily waste

Ports where reception and treatment facilities should be established, according to Activity 1 and 2, are highlighted in grey.

Port	Ballast (m^3/year)	Tank washings (m^3/year)	Bilge water (m^3/year)	Sludge, residues (m^3/year)
Dubrovnik	0	0	450	350
Omisalj	0	2340	200	150
Ploce	0	0	2.625	1.750
Plomin	0	0	0	0
Rijeka-Rasa	0	0	3.200	2.963
Sibenik	0	0	0	0
Split	0	0	4.964	3.103
Zadar	0	0	2.970	1.898

The proposed typical facilities for these ports regarding oily waste are summarized in the table below. Reference is made to chapter 5.2 and Annex E for details regarding the proposed facility.

	Treatment facility	Cost estimate (x€ 1,000)	Remarks/assumptions
Omisalj	1 Reception tank 1 Slop Oil tank 1 Modules A 1 Module B Sludge dewatering	8,500	See below
Ploce	Module A-III	1,700	Existing treatment plant outdated. Revamp preliminary calculated as implementation of a Module A-III.
Rijeka-Rasa	1 Module A-I 1 Module A-I	1,350	New (port based) oil treatment facility for ships other than oil tankers.

Module A: storage of slops/residues + oily water storage and treatment

Module B: slops/oily residues treatment

Omisalj

A joint facility for the Omisalj Oil terminals was recommended. In terms of treatment steps, it will be similar to the design as described in Annex F, but the holding tanks and the design flow rates are much larger:

- the volume of the oily water reception tank will be 7,000 m^3;
- the volume of the slop oil tank will be 1,000 m^3;
- the design flow rate of the wastewater treatment (Module A) will be 450 m^3/h,
- the design flow rate of the oil dewatering (Module B) will be 10 … 30 m^3/h,
- Module C should be replaced by mechanical dewatering with decanter centrifuges (similar to Module B)

As an indication, such a facility could cost approximately € 8.5 million.

Garbage

In Croatian harbors no additional garbage facilities are required with one minor exception, which is Plomin. Here it is recommended to separate food waste from the remaining garbage.

In order to comfort food waste handling it must be recommended to keep food wastes already separate on board and to ground it prior to storage in special food waste tanks.

5.6 Recommendations Slovenia

Oily waste

Ports where reception and treatment facilities should be established, according to Activity 1 and 2, are highlighted in grey (so for Koper there is no need to do so).

Port	Ballast (m^3/year)	Tank washings (m^3/year)	Bilge water (m^3/year)	Sludge, residues (m^3/year)
Koper	0	0	5.250	3.150

No additional facilities are required with reference to oily waste.

Garbage

No additional facilities are required regard to garbage.

6 Cost recovery and institutional setting

The discussion about the recovery of the costs for operating port reception facilities seems to be a never ending story. Ship owners are relatively reluctant to pay for their ship-generated waste treatment, while the authorities in many countries do care about the environmental hazards of dumping ships' wastes into the seas. Port Authorities are also concerned about competitiveness since costs for waste reception and treatment may adversely influence the cost level of as port.

To whom the tariffs for waste treatment and collection should be paid is very different per port and depends largely on the level and allowance of private participation in port activities.

6.1 Institutional setting of ports

It may be relevant to describe in more detail the current situation with regard to the establishment and operations of port reception facilities. In fact a couple of options do exist in ports worldwide, which appear to be heavily related to the level of privatization of port operations in general. Port operations, including cargo handling, can be distinguished into the following four institutional settings:

- *Landlord* model, where <u>private companies operate the terminals</u> (cargo handling), while (municipal, regional or national) port authorities are responsible for safety & environment in the port as well as its development. In such cases, the port authority owns the land and quay walls, while the private companies lease the territory and quay walls, but also invest themselves in the terminal infrastructure (cranes, equipment, buildings, warehouses and alike).
- *Tool* port model, where <u>private companies lease the terminal facilities</u> from a port authority, including cranes, warehouses and alike.
- *Service* port model, where the port authorities handle cargoes themselves and <u>no private company is involved in cargo handling</u> at all.
- *Private* port model, where a –generally large- (private) company (like refineries, quarries, factories) own and operate the port and terminal facilities themselves. In many cases, there is only one user, i.e. the company owning the terminal itself.

In landlord type of ports, port reception facilities are also often privatized with possibly the exception of garbage collection and treatment, which is often the authority that is responsible for the collection of municipal waste. Larger liquid bulk terminals (as e.g. import/export terminals, refineries, chemical complexes) have often their own facilities, or a private liquid bulk collection and treatment company is providing these services with barges berthing alongside the tankers to collect the oily waters.

At tool and service ports, predominantly the authorities themselves are taking care of ship generated waste collection and treatment. Often this is managed by a separate department of the municipal waste utility. These activities are rarely privatized.

Obviously in all port models, monitoring the waste treatment by either the private or public entities is critical for a sustainable treatment of ships' liquid or solid wastes. In some cases, uncontrolled dumping takes place because of lack of proper legislation, ineffective monitoring practices or lack of knowledge and understanding of environmental consequences of this practice.

6.2 Cost recovery

Basically there are two ways to recover the costs of investing and operating port reception facilities:

- Directly, where the ship owner (or its agent) pays directly the fees, based on tonnage, to the operating waste company;
- Indirectly, where the recovery costs are included in the harbor and port dues. Here the port authority either recovers its own costs for the port reception facility or transfers part of the fees to the waste operating company.

In Annex G a summarized table is attached of the available tariff / fee structures in those ports where port reception facilities are available and implemented, based on the outcomes of Activities 1 and 2. One conclusion is clear from these tables, namely that a wide variation exists in how to structure the fee structures (on tons, m^3 or other units).

In general fees for waste collection and treatment are normally levied on a ton or m^3 basis. In order to allow the respective terminal and port operators in the three Mediterranean countries to calculate themselves the possible fee structure, we included a very basic calculation model, in which some rudimentary calculations can be made to assess fees per unit to recover the costs of the (investments and operational costs of the) facilities. An example of a calculation is presented in Annex H. Basic parameters in this model are e.g.:

- Investment / capital costs (and depreciation period);
- Operating costs based on labor, power, fuels and alike;
- Maintenance costs;
- Land lease costs (number of square meters used);
- Tons or m^3 of waste.

It is difficult to present benchmark fees and tariffs, since the variety of fee structures is very large. Differentiating fees are based on a/o:

- Time of the day the services have to be provided (night vs. daytime);
- Distance from the facility itself;
- Necessity of transport between the vessels and the port reception facilities;
- Type of transport mode used (barge or truck);
- ‘Quality’ of the waste or minimum / maximum contamination levels.

6.3 Developments in Europe in cost recovery systems

It has been recognized that a direct fee system provides a disincentive for ships to deliver wastes: costs for waste can be avoided if a ship does not deliver waste. While environmental consciousness is increasing in the shipping industry, illegal discharges at sea are still quite common.

To reduce these discharges, EU-directive 2000/59/EC on ship generated wastes contains amongst others:

- mandatory delivery of waste ;
- preparation of port waste management plans;
- a notification system;
- indirect cost recovery: ships should contribute to the costs of waste collection and treatment, whether they discharge waste in a port or not.

These elements should lead to a significant decrease discharges at sea and a much better utilization of port reception facilities. It is not necessary that all costs related to waste collection and treatment should be covered by this indirect fee system: it is stated that, as a minimum, 30% of the cost should be covered by the indirect fee.

Indirect fee systems are already applied for a considerable time in the Baltic Sea. Generally speaking, these systems are 100% indirect. A ship pays a compulsory fee for which it is allowed to discharge (sometimes a limited amount of) oily waste.

The effect of an indirect fee system, in terms of the volumes of waste which are delivered is difficult to asses, due to lack of data. In the Baltic Sea, it is claimed to have increased the volumes, but the real effect is not well documented. In other countries in Western-Europe, the indirect fee system is being introduced but there are no data yet to substantiate the effect. In the port of Rotterdam, a study[4] has been carried out to estimate the potential effect of mandatory delivery. The report concludes that an increase with a factor 2 - 3 may be expected.

An argument which has lead to heated debate is the 'level playing field'. In many cases it is argued that introducing an indirect fee system increases the overall cost level of a port and thereby jeopardizes the competitiveness of a port compared to other ports which do not introduce the indirect system. Many arguments against or in favor of this issue have been put on the table. The overall effect now seems to be that, to be on the safe side, several countries will start with the minimum percentage of 30% indirect, which may be increased in the future. Discussing benefits and drawbacks of a direct versus an indirect cost recovery system is one thing. We assume however, that avoiding costs by not providing reception facilities is not an issue anymore.

In the Mediterranean, a joint approach to the issue of direct versus indirect cost recovery may be considered. Like the Baltic Sea, it is a confined sea where pollution tends to accumulate. On the other hand, the number of countries involved in the Mediterranean is higher than the in the Baltic Sea which will make it more difficult and time consuming to identify a common approach. There is also the point that EU-member states have the obligation to implement the EU-Directive, non EU-member states do not have that obligation.

In this stage, it is not possible to provide clear recommendations on this very complex issue. However, if it has not been done yet, it is advisable to learn from the experience in the Baltic Sea and to that end it is advisable to consult HELCOM. Also, the ongoing introduction of the EU-directive in EU-member states is an operation from which lessons can be learned.

[4] H. Braun, S. Doves: The Port of Rotterdam and a mandatory delivery system for ship-generated waste, December 1998.

7 Conclusions and recommendations

7.1 General

1. The work that was carried out under Activity 1 and 2 was unknown at the time when Tebodin prepared the proposal for Activity 3. Nevertheless, the reports on Activity 1 and 2 proved to be a solid basis for the work carried out by Tebodin.
2. The selection of **collection** equipment is highly determined by the local situation in each port, and recommendations were already prepared in Activity 1 and 2. Some guidance on the criteria to be applied for selecting the appropriate means for collection was provided. The recommendations as provided in Activities 1 and 2 appear to be correct, and Tebodin has not reached other conclusions.
3. A variety of techniques have been investigated for **treating** oily wastes. A multi-criteria evaluation of these techniques was carried out, resulting in a ranking of all techniques which were discussed. The results are:
   - for oily water (which contains free oil and may also contain emulsified oil): a tilted plate separator followed by coagulation-flocculation and a dissolved air flotation unit is the preferred option;
   - for treatment of recovered oil to remove solids and water: a centrifuge is the preferred option;
   - for treatment of residual sludge's from the waste water treatment: drying bed or lagoon is the preferred option.
4. Options for recycling recovered oil (such as re-refining) are very limited, since the volumes of oil in each port do not justify setting up a dedicated facility.
5. For a number of ports, minimal collection services are recommended, since the estimated volumes of oily waste are very small. However, there is not much point in receiving oily waste without a possibility of treatment in accordance with the applicable environmental regulations and it may also be considered not to receive oily waste in these ports.
6. Garbage is – almost without exception – brought to landfills and there is practically no information on recycling schemes for municipal garbage. It also appeared that the volumes of ship generated do not justify setting up a dedicated recycling scheme. Nevertheless, information on garbage separation techniques is provided as background reading material.
7. For final disposal of wastes (garbage and de-watered sludges), various options were reviewed and, after a multi-criteria analysis, a controlled landfill is the recommended option. For the sake of comparison, an uncontrolled landfill was also included in the analysis, though Tebodin does not recommend uncontrolled land filling in any case.
8. For reception and treatment of oily wastes, typical facilities were developed with standard holding volumes and treatment capacities. These typicals can be used in various ports. These designs can be fine-tuned to the specific requirements in each port regarding holding volumes, treatment capacities and type of treatment.
9. Cost estimates were prepared for the typical facilities. The estimates should be used with caution and provide indications only.

7.2 Recommendations per port

1. In the recommendations per port, Tebodin has followed the conclusions as presented in the reports on Activity 1 and 2, regarding ports where facilities should be established.
2. In ports were a refinery is operating, it is recommended that the refinery processes the recovered oil and that it also processes sludge's from the waste water treatment unit. This is by far the cheapest solution. Obviously, it may require discussions and negotiations to materialize this recommendation. Some Mediterranean countries already have a recycling scheme in place and recovered oil should fit in this scheme. In other ports, a final disposal option for oil must be found.
3. For ports where the typical facilities are not appropriate, specific recommendations were prepared as far as possible. These address in particular 'brown field' situations, i.e. reception and treatment facilities may already exist which may or may not be appropriate and modifications may be required. When further design work will be carried out in Activity D, we recommend that for these ports a field inspection is carried out, to determine the condition and performance of the existing facilities and to assess whether reusing components is feasible or not.
4. Collection of wastes from ships is in many ports done by private contractors. In a number of ports additional collections means as trucks and barges are recommended in the reports of activity 1 and 2. A decision must be taken to either invest in collection or to contract it out to private contractors. In the cost estimates for (typical) facilities, we have assumed that the collection services will be contracted through private companies.
5. It would be beneficial for the relevant authorities in the respective countries, where (additional) port reception facilities are suggested, to support them in the preparation of viability assessments including engineering, detailed costs estimates, tender documents as well as the financial recovery / tariffs to be charged (the latter through an inter-active financial tool).

Annex A: Summarized tables of Activities 1 and 2

Albania

Tabel I - Cargo handled in the main ports of Albania in 2000 (x 1,000 tons)

Total cargoes handled	**2,532**
Liquid bulk	224
Containers (in TEU)	354
Solid bulk and general cargoes	2,307
Other cargoes	n.a.
Unloaded cargoes	n.a.
Loaded cargoes	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel II - Total number of ships calls per type of ship in 2000, 2001 and 2002 in main ports of Albania

Type of ship	**Durres**			**Vlore**			**Shengjin**			**Saranda**		
	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002
Container	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cruise and passenger	1,978	1,683	1,749	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	765	876	987
Dry bulk and general Cargo	1,142	1,089	1,098	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	56	58	60
Ro-Ro	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Type of ship	**Durres**			**Vlore**			**Shengjin**			**Saranda**		
	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002
Tankers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel III - Estimated generation of oily wastes and capacities available in main ports of Albania (x m³ per year)

Type of waste		Durres	Vlore	Shengjin	Saranda
Dirty ballast	annual volume	n.a.	n.a.	n.a.	n.a.
	volume per ship arrival	n.a.	n.a.	n.a.	n.a.
Tank washings	annual volume	n.a.	n.a.	n.a.	n.a.
	volume per ship arrival	n.a.	n.a.	n.a.	n.a.
Oily bilge water	annual volume	4,233.3	958.5	784.2	900.0
	volume per ship arrival	20.0	10.0	10.0	10.0
Oil residues (sludge) and other waste oils	annual volume	2,061.7	443.7	310.2	150.0
	volume per ship arrival	15.0	7.5	7.5	7.5

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel IV - Estimated generation of garbage and capacities available in main ports of Albania (x m³ per year)

Type of waste	Durres	Vlore	Shengjin	Saranda
Domestic waste	3,395.6	316.2	167.1	234.6
Maintenance waste	176.0	242.0	60.2	112.6
Cargo related waste	n.a.	n.a.	n.a.	n.a.
Total volume of garbage	3,571.6	558.2	227.3	347.2
Maximum volume per ship	5.0	5.0	3.5	3.5
Cost of delivery (in US $)				

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Croatia

Tabel I - Cargo handled in the main ports of Croatia in 2000 (x 1,000 tons)

Total cargoes handled	**3,748**
Liquid bulk	364
Containers (in TEU)	11
Solid bulk and general cargoes	3,384
Other cargoes	n.a
Unloaded cargoes	n.a
Loaded cargoes	n.a

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel II - Total number of ships calls per type of ship in 2000, 2001 and 2002 in main ports of Croatia

Type of ship	**Dubrovnik**			**Ploce**			**Split**			**Zadar**			**Sibenik**			**Rijkeka - Rasa**			**Plomin**	
	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001
Container	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cruise and passenger	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	30	400	550	n.a.	n.a.
Dry bulk and general Cargo	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	731	712	719	n.a.	n.a.
Ro-Ro	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Type of ship	**Dubrovnik**			**Ploce**			**Split**			**Zadar**			**Sibenik**			**Rijkeka - Rasa**			**Plomin**	
	2,000	2,001	2,002	2,000	2,001	2,002	2,000	2,001	2,002	2,000	2,001	2,002	2,000	2,001	2,002	2,000	2,001	2,002	2,000	2,001
Tankers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel III - Estimated generation of oily wastes and capacities available in main ports of Croatia (x m³ per year)

Type of waste		Dubrovnik	Ploce	Ploce, terminal Energo petrol	Omisalj oil terminal	Split	Zadar	Sibenik	Rijeka - Rasa	Plomin
Dirty ballast	Average annual volume	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Max. volume per ship arrival	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tank washings	Average annual volume	n.a.	n.a.	2,340.0	74,250.0	n.a.	n.a.	n.a.	n.a.	n.a.
	Max. volume per ship arrival	n.a.	n.a.	300.0	2,250.0	n.a.	n.a.	n.a.	n.a.	n.a.
Oily bilge water	Average annual volume	450.0	2,625.0	300.0	150.0	4,964.0	2,969.5	n.a.	3,199.5	n.a.
	Max. volume per ship arrival	25.0	25.0	15.0	30.0	25.0	25.0	n.a.	30.0	n.a.
Oil residues (sludge) and other waste oils	Average annual volume	350.0	1,750.0	150.0	247.5	3,102.5	1,898.0	n.a.	2,962.5	n.a.
	Max. volume per ship arrival	15.0	15.0	30.0	25.0	15.0	15.0	n.a.	15.0	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel IV - Estimated generation of garbage and capacities available in main ports of Albania (x m³ per year)

Type of waste	Dubrovnik	Ploce	Split	Zadar	Sibenik	Rijeka - Rasa	Plomin
Domestic waste	1,325.3	700.0	6,000.0	2,100.0	n.a.	1,185.0	n.a.
Maintenance waste	92.0	154.1	277.9	133.7	n.a.	260.7	n.a.
Cargo related waste	n.a	308.6	111.2	102.6	n.a.	252.5	n.a.
Total volume of garbage	1,417.3	1,008.6	6,389.1	2,336.3	0.0	1,698.2	0.0
Max. volume per ship arrival	10.0	5.0	> 5,0	> 5,1	n.a.	5.0	n.a.
Cost of delivery (in US $)							

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Slovenia

Tabe I - Cargo handled in the main ports of Slovenia in 2000 (x 1,000 tons)

Total cargoes handled	**2,950**
Liquid bulk	1,991
Containers (in TEU)	991
Solid bulk and general cargoes	958
Other cargoes	n.a.
Unloaded cargoes	n.a.
Loaded cargoes	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel II - Total number of ships calls per type of ship in 2000, 2001 and 2002 in main ports of Slovenia

Type of ship	**Koper**		
	2000	2001	2002
Container	n.a.	n.a.	n.a.
Cruise and passenger	n.a.	n.a.	n.a.
Dry bulk and general Cargo	n.a.	n.a.	n.a.
Ro-Ro	n.a.	n.a.	n.a.

Type of ship	**Koper**		
	2000	2001	2002
Tankers	n.a.	n.a.	n.a.

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel III - Estimated generation of oily wastes and capacities available in main ports of Slovenia (x m³ per year)

Type of waste		Koper	Instalacij O.T. Koper
Dirty ballast	Average annual volume	n.a	n.a
	Max. volume per ship arrival	n.a	n.a
Tank washings	Average annual volume	n.a	n.a
	Max. volume per ship arrival	n.a	n.a
Oily bilge water	Average annual volume	5,250	643
	Max. volume per ship arrival	25	25
Oil residues (sludge) and other waste oils	Average annual volume	3,150.0	464.1
	Max. volume per ship arrival	20.0	7.5

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Tabel IV - Estimated generation of garbage and capacities available in main ports of Albania (x m³ per year)

Type of waste	Koper
Domestic waste	1,890.0
Maintenance waste	4,620.0
Cargo related waste	119.6
Total volume of garbage	2,471.6
Max. volume per ship arrival	5.0
Cost of delivery (in US $)	

Port reception facilities for collecting ship-generated garbage, bilge water and oily wastes in Albania, Croatia and Slovenia - Activity 1 & 2, February 2004

Annex B: Overview of garbage quantities from ships per port

Estimated volumes of garbage, according to Activity 1					
	Country	**Domestic waste (m3/annum)**	**Maintenance waste (m3/annum)**	**Cargo related waste (m3/annum)**	**Total garbage (m3/annum)**
Durres	Albania	3,396	176	-	3,572
Saranda	Albania	235	113	-	347
Shenghjin	Albania	167	60	-	227
Vlore	Albania	316	242	-	558
Dubrovnik	Croatia	1,325	92	-	1,417
Osmalj Oil terminal	Croatia	n.a	n.a	n.a	-
Ploce	Croatia	700	154	309	1,163
Rijeka Rasa	Croatia	1,185	261	253	1,698
Split	Croatia	6,000	278	111	6,389
Zadar	Croatia	2,100	134	103	2,336
Koper	Slovenia	1,890	462	120	2,472
Total		**17,314**	**1,972**	**896**	**20,179**

Legend:

n.a. = not available

Annex C: Background information on technologies for garbage treatment

1 Background information on technologies for garbage treatment

The main unit operations can be distinguished as follows:

- Size reduction;
- Separation.

1.1 Size reduction

In the cases that a mixed solid waste feed (except food waste) is offered to the reception facilities, it is essential to reduce the size of the material prior to further processing. This can be done by crushing and deforming in special equipment en will result in a density increase of the garbage. Typical equipment for that purpose are:

- Cutters;
- Shredders;
- Grinders.

1.1.1 Shredders

Shredders quickly reduce a variety of bulk solids with their high torque shredding action. These units reduce the scrap volume up to 80%. By applying different knife profiles the shredder can be designed to treat specific materials like metal scrap, wood, plastic, rubber or other garbage materials.

There are different designs possible like single shaft, high torque, low speed shear shredders for size reduction of baled materials or twin shaft, high torque, low speed shear shredders for size reduction of general waste (electrical motor power 15kW - 320kW).

1.1.2 Grinders

Waste grinders are often used wood, plastic, rubber or garbage materials.

The equipment can be operated by one operator and uses a high speed grinding design to quickly reduce waste (drive engine power 1.5kW - 300kW)..

1.2 Separation

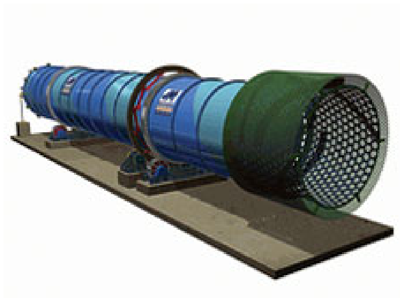
If waste segregation does not take place on board, technical equipment can separate the waste into a number of main categories e.g.:

- plastics;
- glass;
- metal;
- other solid waste.

1.2.1 Screens

Wedge wire and shaking bar dewatering screens are designed with eccentric weight vibratory motor drives for both for fixed and mobile installations. A trommel is a rotary cylindrical screen that is typically inclined at a downward angle that, combined with the tumbling action of the trommel, separates materials of different density. Trommel screens are used to separate mixed recyclables, municipal solid waste components, or to screen finished compost from windrow and aerated static pile systems.

Vibrating Wedge wire



Trommel Screen

Trommel screens are used by material recovery facilities to separate paper from glass and other contaminants in previously shredded municipal solid waste. Smaller trommels have been used to separate labels and caps from crushed glass. Some trommels are designed to let paper pass through the screen while diverting heavier materials to re-crushing or a landfill. Other applications require multi-stage trommel screens which have meshes or plates of different aperture sizes.

1.2.2 Magnetic separation

Sorting and separating ferrous metals using magnetized systems has been standard practice for many years. Recovering non-ferrous metals, however, was a labor intensive, costly and a time consuming exercise.

Most magnetic metal separators are built around either cartridge magnets or plate magnets. While some options for these separators may need electric or pneumatic connections, the permanent magnets themselves require no external power.

In general, the choice between these two basic types depends largely on the characteristics of the materials which must be treated and the material handling system.

The Self-Cleaning Recycling Magnets are Permanent Magnets using the latest and highest grade of materials suitable for this type system. When compared to electro magnets, no electrical source is required for the magnet, it is considerably lighter in weight, has a lower profile, is virtually maintenance free and less expensive to purchase, install and operate.

Annex D: Indication of recoverable oil volumes per port

Volumes of recoverable oil						
Port	**Country**	**Ballast (m3/year)**	**Tank washings (m3/year)**	**Bilge water (m3/year)**	**Sludge, residues (m3/year)**	**Total recoverable oil (tons/annum)**
Durres	Albania	0	0	4,233	2,062	563
Saranda	Albania	0	0	900	150	50
Shenghjin	Albania	0	0	784	310	87
Vlore	Albania	0	0	959	444	122
Dubrovnik	Croatia	0	0	450	350	91
Osmalj Oil terminal	Croatia	0	74,250	150	248	1,844
Ploce	Croatia	0	2,340	3,001	150	140
Rijeka Rasa	Croatia	0	0	3,200	2,963	762
Split	Croatia	0	0	4,964	3,103	824
Zadar	Croatia	0	0	2,970	1,898	503
Koper	Slovenia	0	0	5,250	3,150	840
Total		**0**	**76,590**	**26,861**	**14,828**	**5,827**

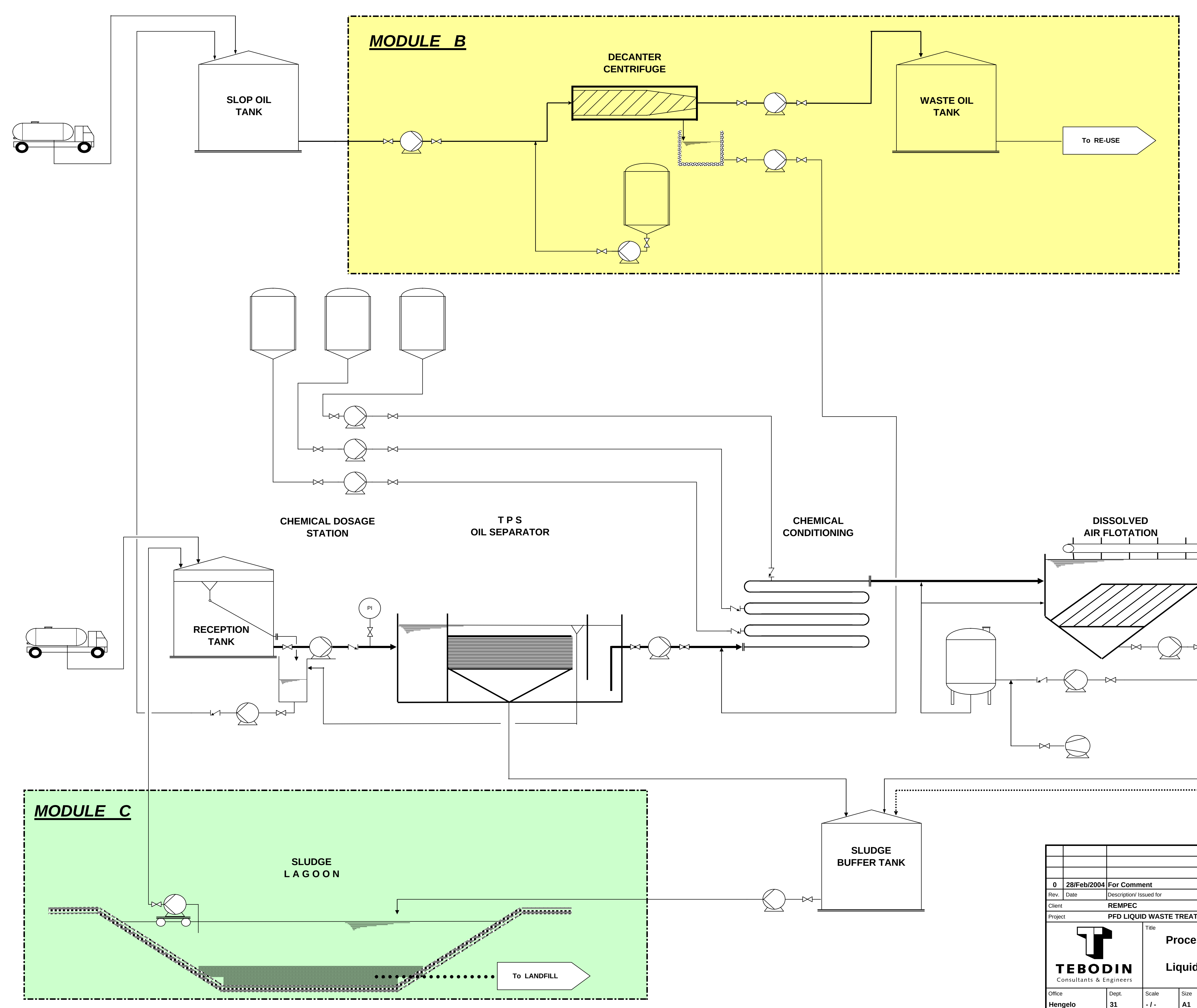
Legend
1. Ports where facilities are proposed, but where no outlet exists for oily
2. Port where facilities are proposed and outlet for oil exists (refinery e.a.)
3. It is assumed that 80% of the average oil content is recovered.
n.a. = not available

Annex E: Calculations for treatment facilities

Port	Country	Tank washings (m3/year)	Bilge water (m3/year)	Average week (m3/week)	Average day (m3/day)	Average flowrate (m3/h/)	Proposed storage in Activity 1&2 (m3)	Proposed treatment in Activity 1&2 (m3/h)
Durres	Albania	0	4,233	81.4	16.9	2.1	n.a.	n.a.
Saranda	Albania	0	900	17.3	3.6	0.5	n.d.	n.a.
Shenghjin	Albania	0	784	15.1	3.1	0.4	n.d.	n.a.
Vlore	Albania	0	959	18.4	3.8	0.5	n.d.	n.a.
Dubrovnik	Croatia	0	450	8.7	1.8	0.2	n.a.	n.a.
Osmalj Oil terminal	Croatia	74,250	150	1430.8	297.6	37.2	8.000	study required
Ploce	Croatia	2,340	3,001	102.7	21.4	2.7	n.a.	upgrade exist.
Rijeka Rasa	Croatia	0	3,200	61.5	12.8	1.6	70	10
Split	Croatia	0	4,964	95.5	19.9	2.5	n.a.	n.a.
Zadar	Croatia	0	2,970	57.1	11.9	1.5	n.a.	n.a.
Koper	Slovenia	0	5,250	101.0	21.0	2.6	n.a	n.a.

Legend:
n.d. = not determined
n.a. = not applicable

Annex F: Flow diagram of typical reception and treatment facility



NOTES

Item	Module	Volume/Flow
Reception Tank	A I	100 m^3
TPS	A I	10 m^3/h
DAF	A I	10 m^3/h
Sludge Buffer Tk	A I	50 m^3
Slop Oil Tank	A I	50 m^3
Decanter	B I	1...5 m^3/h
Waste Oil Tank	B I	50 m^3
Reception Tank	A II	150 m^3
TPS	A II	20 m^3/h
DAF	A II	20 m^3/h
Sludge Buffer Tk	A II	50 m^3
Slop Oil Tank	A II	100 m^3
Decanter	B II	1...5 m^3/h
Waste Oil Tank	B II	50 m^3
Reception Tank	A III	200 m^3
TPS	A III	50 m^3/h
DAF	A III	50 m^3/h
Sludge Buffer Tk	A III	200 m^3
Slop Oil Tank	A III	100 m^3
Decanter	B III	5...10 m^3/h
Waste Oil Tank	B III	100 m^3

Rev.	Date	Description/ Issued for	Drawn by	Ckd	Seen by
0	28/Feb/2004	For Comment			

Client: **REMPEC**

Project: **PFD LIQUID WASTE TREATMENT**

TEBODIN
Consultants & Engineers

Title

Process Flow Diagram

Liquid Waste Treatment

Office	Dept.	Scale	Size	Ordernumber	Sub	Drawingnumber	Sht	of	Rev.
Hengelo	31	- / -	A1	32381	00	3142001	1	1	0

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Annex G: Overview of available reception facilities based on Activities 1 and 2

Country	Port / Terminal	Method of treatment of oily wastes	Charging system	Other remarks
Albania	Durres	Settling, heating and air induced oil water seperation (1) 20 tons/day; (2) 500 it/hour	No information	
Croatia	Ploce	Mechanical settling and seperation only, No secondary treatment of waste water.	Vebecot d.o.o. and Pomorski SLP d.o.o. charge $US per cub. Meter collected	
	Ploce, Vlaska channel	Mechanical settling and seperation only, No secondary treatment of waste water.	No information	
	Split	Mechanical settling carried out to separate oil before its furthur filtration and homogenisation.	No information	
	Port of Rijeka	Treatment is effected through primary settling, recovery of separated oil throug surface skimming and finally through an open, API separator for the water phase that achieves a 750 cub. Secondary treatment for the water effluent.	No information	
	Rijeka Bakar bay	Mechanical settling and seperation at 750 cub. meters/hour	25 euros/ton collected	Oilrecovered from the separation and treatment process is send to the oil refinery slop tank used to hold drainage and other waste oils produced in the oil storage tanks. Sludge produced from the AIP equipment is treated in a decanter/centrifuge unit, while the oily sediments are mixed and stabilized with quicklime to be disposed of within the area of the refinery.
Slovenia	Koper	Bilge water is treated, through port based a DAF unit, filtering and ozonation systems. Used oils and sludge is collected by Ecoles road tankers.	A direct fee depending on the quality and the actual quantity of the oily wastes deliverd applies varying from 100 - 500 $US per cubic meter for bilge water free of oil to sludge.	

Annex H: Example of rudimentary calculation of port reception tariffs

Note: *Depreciation period* *20 Years*

Costs item		Costs (* 1.000)
Investment costs		
Investment for installation		€ 208
Land (M²)	2445	
Costs per M² land	€ 150	
Land costs		€ 367
Operating costs (yearly base)		
Employees	17	
Labour costs per employee		€ 1
Labour costs per year		€ 17
Labour costs total		
Power		€ 1
Fuels		€ 1
Transport		€ 15
Management		€ 6
Capital costs		
Interest per year		€ 0
Total		**€ 616**

	Type of oily waste	Number of M³
☑	Dirty ballast	20,147
☑	Tank washing	10,280
☑	Oily bilge water	10,264
☑	Oil residues (sludge) and other waste oil	4,769
	Total	**45,460**

Costs per M³ oily waste **€ 14**