App. 7 Data sheets on (pre-)treatment and final disposal

PRE-TREATMENT	Screening
Description	Separation of the polluted solid waste and sand and pebbles from the liquid phase (oil and/ or water). Screening is the term used for large particles (few cm's, French equivalent is "dégrillage", and few 10's of dm, French equivalent is "criblage"). Sieving is the term used for smaller particles (few mm's, French equivalent is "tamisage"). Note. Some equipment are specifically designed to sort out metal from non-metal elements (and plastic from non-plastic), using magnetic sorting equipment.
Waste	Liquid Polluted sand and pebbles/ stones Polluted solid waste
Situation / Potential in the country in the country	Use of public work/ construction work equipment easy to import and implement in any country.
Interest	Allows segregating the solid and sediment from the liquid phase for more specific waste treatment.
Entry criteria	Any type of liquid with semi-solids and solid, polluted sand/ pebbles/ solid waste.
Operational constraints	Requires personnel, specific screening equipment, energy, and storage for segregated material. May not be carried out on heavy / weathered / emulsified oil trapped in sediment without fluidization. Possible installation ranges from simple screen to heavy industrial screening equipment.
Impacts	Minimal if equipment is suitable, correctly operated and there are no oil leaks.
Legal constraints	Refer to those applying to the transport, handling and storage of oil products.
Efficiency	Depending on equipment.
Cost	CAPEX and OPEX vary widely depending on the installation purchased/ rented.

PRE-TREATMENT	Size sorting
Description	Sorting of the sediments (and other waste) based on their size (fine sediment, sand, gravel, pebble, cobble, boulder).
Waste	Polluted sand and pebbles/ stones
Situation / Potential in the country in the country	Use of public work/ construction work equipment easy to import and implement in any country.
Interest	Some machinery applies to sand, other to gravel, others to pebble and cobble. Most organic and inorganic contaminants tend to bind to the fine fraction of a soil (i.e. clay and silt). Thus, separating the fine clay and silt particles from the coarser sand and gravel soil particles concentrates the contaminants into a smaller volume of soil that can then be treated or disposed.
Entry criteria	Any type of semi-solids and solid, polluted sand/ pebbles/ solid waste.
Operational constraints	Requires personnel, specific sorting equipment, energy, and storage for the sorted sediment. May not be carried out on sediment trapped in heavy / weathered / emulsified oil without fluidization (because oil fills in the pores of the sorting equipment).
Impacts	Minimal if equipment is suitable, correctly operated and there are no oil leaks.
Legal constraints	Refer to those applying to the transport, handling and storage of oil products.
Efficiency	Depending on equipment, can allow sorting waste / various size of sand and pebbles (depending on the screen used in the machine). The size of the installation ranges from simple sorting equipment (few 10's of cubic metres per hour) to heavy of industrial equipment, e.g. Trommel screening type (screened cylinder used to

	separate materials by size, 200 to 300 cubic metres per hour).
Cost	CAPEX and OPEX vary depending on the installation purchased/ rented.
PRE-TREATMENT	**Mills/ Shredders/ Shearing machines/ Crushers**
Description	Equipment used to downsize the solid waste. Equipment used depends on the type of waste. • Mills: breakable solid waste • Shredders: cardboard, polystyrene • Shearing machines: plastic, paper, cardboard, wood • Crushers: wood/ log, rubble, plastic, large pieces of waste
Waste	Solid waste Mineral waste (gravel, pebble, boulder)
Situation / Potential in the country	Equipment can be imported and implemented easily.
Interest	Allows preparing smaller size material for treatment (e.g. incineration, co-incineration etc.).
Entry criteria	Depends on the type of equipment.
Operational constraints	The equipment wears off very rapidly. Main pieces must be changed frequently.
Impacts	Environmental impacts are limited to the noise.
Legal constraints	Limited.
Efficiency	Very good when implemented adequately.
Cost	CAPEX: price of the equipment ranges from few thousands Euros to few millions Euros depending on the capabilities and complexity of the equipment. OPEX vary accordingly.
PRE-TREATMENT	**Drying of sea weed**
Description	Drying of oiled sea weed and sea grass before incineration. Sea weed and sea grass are disposed in piles (e.g. 2m x 2m), height must not exceed 20 cm.
Waste	Sea weed and sea grass lightly (to medium) oiled
Situation / Potential in the country	Pre-treatment can be implemented very easily with limited equipment (earth moving equipment).
Interest	Allows decreasing the overall weight of a minimum of 50% of the sea weed and grass (and removing water) before incineration, thus reducing the cost and facilitating the incineration.
Entry criteria	Drying is used for lightly to medium oiled marine vegetal waste.
Operational constraints	The drying requires non sensitive land areas. Ground must be protected to avoid infiltration.
Impacts	Environmental impacts are limited to the odours (if infiltration is managed).
Legal constraints	Limited
Efficiency	In temperate country, sea weed dries off in 15 days, less on hotter conditions.
Cost	Limited to the rental cost of earth moving machines, personnel and land.
PRE-TREATMENT	**Decantation (settling)**
Description	Separation of a liquid phase (oil or oily water) from another phase (liquid and/ or solid) either on the field during response operations or after the response operations in specialized installations (refinery, deballasting stations, etc.).
Waste	Liquid (may contain limited volumes of semi-solids and solid)
Situation / Potential in the country	Equipment easy to implement in any country (requires tanks for settling and storage, and pumps able to pump water and oil).

Interest	Allow separating oil and water from an oil and water mix (may also allow recovering sediment depending on equipment). During response operations, it can be accepted that the separated water is discharged in the environment thus reducing the need for storage capabilities (on the working sites and on the spill response vessels recovering oil offshore).
Entry criteria	Any oil, water and solid particle mix may be decanted to a certain degree. Oil and water cannot be recovered directly from emulsified oil. The de-emulsification is necessary prior to decantation.
Operational constraints	Requires personnel, a suitable site and storage capabilities for the recovered oil, water and solids (and/ or the possibility to discharge the recovered water in the environment).
Impacts	➔ First decantation on the field during the response operations: the decantation has limited impact. It is often accepted that the recovered water is discharged in the environment (during the spill response operations). ➔ During waste treatment in specialized plants (once emergency response operations is completed): minimal if equipment is suitable, correctly operated and there are no oil leaks.
Legal constraints	Refer to those applying to the discharge of water in the environment. Higher concentrations of oil in water (in the discharged water) are acceptable during spill response operations.
Efficiency	Typical maximum flow rate depends on the pumps and decantation equipment. ➔ First decantation on the field during the response operations: decantation time depends on the oily water recovered (typical time is one hour). Pumps with typical flow rates of 10 to 50m3/ hr are used. ➔ During waste treatment in specialized plants: few cubic metres to 10's of cubic metres per hour.
Cost	CAPEX, mobilisation cost: • First decantation on the field during the response operations: costs of rental/ purchase for storage tanks (10 m3 or more) and volumetric pumps (10 to 50 m3/ hr flowrate) • None if existing installation OPEX: varies depending on the type of installation; however costs are limited (around 50 euros/ per m3 of waste to decant).
PRE-TREATMENT	**Centrifugation**
Description	Separation of phases: oil - water **–** sediment using specific centrifugation machine.
Waste	Liquid (with limited fraction of sediments, threshold depends on equipment). Simple centrifugation may also be used to recover oil form heavily polluted sands.
Situation / Potential in the country	Equipment easy to import and implement in any country.
Interest	Allow separating oil, water and sediment. Recovered oil may be re-used.
Entry criteria	Typical feed limit characteristics for centrifugation equipment: • **Oily sludge pumpable** by standard volumetric pumps • **Dry solid content : maximum 15 %** • Grain size : no particles bigger than 5 mm (plastic, sand, stones, wood, rust and other materials) • Oil content : 0 - 100 % • Water content : 0 - 100 % Note. Other equipment allow centrifugation of heavily oiled sands.
Operational constraints	Requires personnel, site (surface of 200 m2 minimum), and input: • Electrical supply • Polymer (flocculant) powder can be used to facilitate the recovery of fine sediment (use 10 to 12 kg per ton of dry solid) • Demulsifying chemicals can be used for emulsion. • Water may be required in case of heavy sludge with low water content, to liquefy the product before inputting into the centrifugation machine.
Impacts	Minimal if equipment is suitable, correctly operated and there are no oil leaks.
Legal constraints	Refer to those applying to the transport, handling and storage of oil products.

Efficiency	Typical maximum flow rate : • 750 kg dry solids per hour • 12 m^3/h maximum. Based on experience, 40 to 60 cubic meter of sludge can be treated daily (based on an 8 hours working day). Quality of oil recovered: • Contains 5% < BSW < 10%. Depending on the type of mud and machine tuning. Quality of water output by centrifuge machine: • Contains 2%<oil<10% and 0,1%<SPM<3%. Depending on the mud & machine tuning. • Water can be retreated in a lamellar decanter to reach a content of oil inferior to 0,1% and SPM inferior to 0,1%. Quality of sediment: • Contains 5 < Oil leachate < 10% and 30% < DS < 45%. • Depends on the type of mud, machine tuning and additives (flocculants).
Cost	CAPEX: example of mobilisation cost for centrifugation equipment with above mentioned efficiency: • Trans Mediterranean transport of equipment (2 x open-top containers: 1 x 20 ft container, and 1 x 40 ft container) : approx. 10,000 euros • Installation and start-up: approx. 25,000 euros OPEX: Treatment of 1 cubic meter of sludge (using centrifuge decanter and lamellar decanter for the water and including flocculants and de-emulsifier): approx. 60 euros/ m^3 of sludge treated.
PRE-TREATMENT	**Emulsion breaking**
Description	Breaking up of emulsion of water in oil to water and oil phases, either on site or in a suitable facility plant. Water in oil emulsions are very viscous and may contain up to 50 to 80% of water. ➔ Unstable emulsions can be broken by simple decantation or by heat treatment followed by decantation. The oil/water mixture should preferably be heated by circulation through an external heat-exchanger. ➔ Stable emulsions can be broken up by using demulsifying chemicals, which should be used as early as possible. The recommended dose rate varies with the type of oil and the age of the emulsion, but are usually very low (ranges from 250 to 5,000 ppm). Process lasts a minimum of 10 to 20 minutes.
Waste	Emulsified oil
Situation / Potential in the country	Heating equipment can be easily implemented. Demulsifying chemicals are easy to import and implement in any country.
Interest	Any decrease of the content of water in the emulsion implies less waste to treat afterwards. Water and oil can then be recovered separately using decantation or centrifugation.
Entry criteria	Any emulsified oil.
Operational constraints	➔ Heating. The safe working temperature limits is usually considered to be the flash point of the oil less 8°C. Generally, a working temperature of 60-66°C is used with a maximum temperature of 80°C to maintain operational safety. ➔ Use of demulsifying chemicals. There is no « universal » product. Screening and test will be required.
Impacts	Emulsion breaking: minimal if equipment is suitable, correctly operated and there are no oil leaks. ➔ Demulsifying chemicals may remain in the water after separation so care will be needed when disposing of the water. ➔ The water phase may be discharged in the environment when emulsion breaking is carried out on the recovery site (since the residual oil content is unlikely to increase damage to any species in an area already affected by a significant oil spill). If emulsion breaking is carried out after the clean-up operations, the water recovered should undergo further treatment via a separator unit to further reduce the oil content
Legal constraints	Refer to those applying to the transport, handling and storage of oil products, and discharge of water in the environment.
Efficiency	Generally, after separation into two layers, the water phase contains less than 1,000ppm of oil.

Cost	CAPEX will depend on the type of installation used but will be limited (specially for demulsifying agent). OPEX are also limited as installations are simple, and limited personnel are required (less than 50 euros / m3).
PRE-TREATMENT	**Draining of sorbent**
Description	Draining of oil from sorbent prior to treatment (e.g. incineration) to recover the oil.
Waste	Oiled sorbent (may also be used for heavily oiled solid waste)
Situation / Potential in the country	Easy to implement in the country.
Interest	Allows recovering the major part of the oil for waste from the sorbent before further treatment.
Entry criteria	Any type of sorbent.
Operational constraints	Mainly related to the handling of the oily waste. No other specific technical requirements.
Impacts	Minimal if the oil and sorbent are recovered and managed correctly.
Legal constraints	Refer to those applying to the transport, handling and storage of oil products.
Efficiency	Limited, only to be used to recover bulk oil coating the waste or from sorbent.
Cost	Limited (depends mainly on personnel cost, equipment required is limited).
NATURAL TREATMENT	**Monitored Natural Attenuation**
Description	Comprises a range of physical and biological processes, which, unaided by deliberate human intervention, reduce the concentration, toxicity, or mobility of contaminants. Natural attenuation can be classified as destructive and non-destructive. • Destructive processes include biodegradation, photo-oxydation and hydrolysis. Biodegradation or bioremediation is by far the most prevalent destructive mechanism. • Non-destructive attenuation mechanisms include sorption, dispersion, dilution (most important non-destructive mechanisms) and volatilization.
Waste	Residual pollution (soil and groundwater on site)
Situation / Potential in the country	Does not require any equipment (apart from monitoring capabilities).
Interest	No investment (apart from monitoring capabilities).
Entry criteria	Controversial technique from a public and environmental point of view. May only be considered on residual and biodegradable pollution (or pollution that may be attenuated by the non-destructive mechanism).
Operational constraints	Long-term monitoring is necessary to demonstrate that contaminant concentrations continue to decrease at a rate sufficient to ensure that they will not become a health threat or violate regulatory criteria.
Impacts	Natural Attenuation is not appropriate where imminent risks are present.
Legal constraints	Refer to those applying to polluted soil and groundwater.
Efficiency	To be ascertained by the monitoring program. Research is ongoing.
Cost	Related to the monitoring program (expertise, sampling and analysis).

PHYSICAL TREATMENT	**Washing of oiled sediment and soil** (also known as “Chemical extraction” if solvent are used).
Description	Soil washing uses water to remove contaminants from soils. The process works by either dissolving or suspending contaminants in the wash solution (using hot water, 30° to 50°C and solvent/ dispersant chemical agent when required). It is often used in conjunction with other physical separation techniques (see decantation, centrifugation etc.).
Waste	Contaminated sediment and soil.
Situation / Potential in the country	Equipment may exist in public works, construction industry, mining etc. or mobile units may be imported.
Interest	Soil washing starts by the separation of soil by particle size. Most organic and inorganic contaminants tend to bind and sorb to clay, silt, and organic soil particles. This fine sediment is separated from the remaining soil during the washing by scrubbing, water and possible solvant. Washing does not treat the pollution but also helps removing the pollutants bound to the finer sediments from the coarser sediments and concentrates them in a small volume of oily water, easier to treat and dispose of afterwards.
Entry criteria	The pollutants must be dilutable with solvent (adsorbed to the fine sediment). Soil washing is a technique of concentrating contaminants through separation. It does not destroy or immobilize the contaminants. Consequently, the resulting concentrated contaminated soil and/ or effluents must be disposed of carefully.
Operational constraints	The "clean" portion of the separated soil must be analyzed for residual contamination before it is disposed of as clean material. Sand and gravel are relatively easy to wash. However, mud and clay retain, by adsorption, some oil and will require an additional treatment (Source: Bocard). Wash water requires treatment before it can be discharged, as it usually contains smaller particles or organic particles.
Impacts	Limited if wash waters are managed adequately and treated material is analysed before further treatment or disposal.
Legal constraints	Refer to those applying to polluted soil and groundwater and to the management of oily water.
Efficiency	Depending on the installation, may treat from few 10's of tons of waste per day to few 100's of tons.
Cost	OPEX: around 150 Euros / m3 (Source: KOLLER)

PHYSICAL TREATMENT	**Washing of heavily oiled solid waste**
Description	Washing the solid waste from the oil before the storage or other final disposal using various techniques: ➔ Cold Water Flushing, simple technique, moderately successful, to wash large quantities of oiled debris with a high pressure hose to loosen and float away oil. The resulting oil/water mixture can then be treated via a separator ➔ Warm/Hot Water Flushing to clean pebbles, gravel and sand contaminated with oil or emulsion, using standard mineral processing equipment coupled to a conventional oil/water separator. ➔ High velocity steam jets directed onto an inclined, vibrating, perforated tray placed above a collector to trap oil and condensate, may be used to clean oil-contaminated sand. Possible use of demulsifier. ➔ Solvent Extraction may be considered as a possible mean of removing oil from collected sand, pebbles and debris. Limited research has been carried out in relation to the use of this technique.
Waste	Polluted solid waste and sediment
Situation / Potential in the country	Small installations are easy to implement (however, depends on the size of the equipment).
Interest	Recovery of recyclable material (e.g. plastic and other type of waste). Possibility of incinerating the cleaned waste or storing the cleaned waste in landfills. Possible recovery of oil (if decantation / centrifugation is used after the washing).

Entry criteria	Any type of heavily oiled solid waste or sediment.
Operational constraints	Requires personnel, specific site, washing equipment, energy, washing effluents management facility, cleaning products and large volumes of water.
Impacts	Minimal if the washing effluents are managed correctly. However, requires large volume of water.
Legal constraints	Refer to those applying to the management of oily water.
Efficiency	Depending on the equipment used.
Cost	OPEX: around 150 Euros / m3 (Source: KOLLER) CAPEX and OPEX vary depending on the size and flow rate of the installation.
PHYSICAL TREATMENT	**Flotation (using heated water)**
Description	Flotation of oil from oiled sand in a tank filled with heated water tank (to fluidify the oil) by insufflating air bubbles at the bottom of the tank. The air bubbles mobilize the oil from the sediment and re-float it at the surface of the water.
Waste	Polluted sand
Situation / Potential in the country	Mobile installation may be easily implemented in the country.
Interest	Allows cleaning the sand, which may be returned on the beach (with possible final clean-up using surfwashing).
Entry criteria	Lightly to medium polluted sand (oil from heavily polluted sand should be recovered prior to flotation using e.g. centrifugation).
Operational constraints	Requires the setup of a complete installation, power supply and water supply. Requires effluents management (for the recovered oil and the used water).
Impacts	Minimal if the washing effluents are managed correctly.
Legal constraints	Refer to those applying to the management of oily water.
Efficiency	Flotation is reportedly capable of cleaning about 1 ton of oil contaminated sand per hour. When operating with sand containing up to 2% of oil, approximately 95% of the oil may be removed.
Cost	Varies depending on the size and capabilities of the installation.
PHYSICAL TREATMENT	**Filtration**
Description	Filtration is the physical process whereby particles suspended in water are separated by forcing the fluid through a porous medium (i.e. a filter). The suspended particles are trapped in the filter. Filtration relies on the pore size of the membrane, which can be varied to remove particles and molecules of various sizes. Micro-filtration processes generally work best for separating very fine particles (0.1-0.001 microns) from the liquid.
Waste	Liquid (oil, oily water, water) with sediment (usually fine sediment)
Situation / Potential in the country	Easy to import and implement in country.
Interest	Allows removing the (fine) sediments from a liquid waste before treatment.
Entry criteria	The liquid phase must not be too viscous to flow through the filtering device.
Operational constraints	Limited. The filtering device must be cleaned and/ or changed frequently.
Impacts	Minimal if equipment is suitable, correctly operated and there are no oil leaks.
Legal constraints	Refer to those applying to the transport, handling and storage of oil products.
Efficiency	Depends on the type of installation, few cubic metres to few hundred's of cubic metres per day. Sampling the filtered water monitors the effectiveness of these processes.
Cost	CAPEX depends on the type of installation used (and its capabilities). OPEX are limited to the personnel, power supply and maintenance of the filtering device.

PHYSICAL TREATMENT	**Washing of pebbles (concrete mixer or hot water/ high pressure)**
Description	Cleaning of the pebbles and stones using high pressure and hot water cleaners.
Waste	Polluted pebbles/ stones
Situation / Potential in the country	Required equipment could be sourced in any country
Interest	Allows returning the clean pebbles on the beach.
Entry criteria	Any polluted pebbles and stones.
Operational constraints	Requires personnel, specific site, high pressure cleaner / steam cleaners, energy, washing effluents management facility. Steam cleaners that can work with sea water should be used preferably to limit the use of freshwater.
Impacts	Minimal if the washing effluents are managed correctly and if sea water is used.
Legal constraints	Refer to those applying to the management of oily water.
Efficiency	Depends on the number of cleaner used.
Cost	CAPEX: one high pressure / hot water cleaner working with sea water: 7,000 euros. One portable concrete mixer (benzene engine): 1,000 euros. OPEX is mainly related to the cost of manpower (3 to 4 workers per high pressure machine/ concrete mixer).
	 **Pebble washing on site (Source: Le Floch Depollution)**
PHYSICAL TREATMENT	**Surf-washing**
Description	Cleaning of the polluted sand and pebbles by moving the sediments into the breaking waves zone.
Waste	Medium to lightly polluted sands Medium to lightly polluted pebbles & stones
Situation / Potential in the country	May be tested in every country, requires marine geologist advice and testing in situ.

Interest	Use of the “natural” energy of the waves and return of the sediments on the beach. Low cost and no specific, costly equipment required.
Entry criteria	Usable only for sediments that will remain on the beach and that are lightly to medium polluted.
Operational constraints	Requires personnel and earth moving equipment (to push the polluted sediment in the wave breaking zone and sorbent material to recover the oil.
Impacts	Minimal if the oil is correctly recovered using sorbent.
Legal constraints	Refer to those applying to the management of oily water and quality of coastal water (however, special authorisation should be delivered for such work).
Efficiency	Depending on viscosity and weathering of oil, temperature, exposition to waves.
Cost	CAPEX : none (if local equipment is rented) OPEX for one working site and team: daily cost of one or two mechanical shovel, team of one supervisor, 10 personnel, PPE and sorbent.
STABILISATION TREATMENT	**Stabilisation, using binding agent, e.g. quicklime (semi-solids and solid and oily sands)**
Description	This process comprises two steps: • Solidification: transforms the waste into a granular solid with limited porosity and interesting mechanical characteristics, • Stabilisation: transforms soluble compounds into stable less soluble compounds. The oxydo-reduction reaction of the quicklime with the oil (on the sediments) stabilises the thickest oil compounds and (partially) degrades the lightest compounds of the oil. Stabilisation may be carried out on the working site or in specialized units.
Waste	Semi-solids and solid Polluted sands Note. Liquid waste should not be treated if oil content is too high.
Situation / Potential in the country	Quicklime is easily available and cheap. Other proprietary Hydraulic Binding Materials are also available.
Interest	• Stabilizing the leachate of oil and toxic compounds. • Produces a granular hydrophobic material, physically and chemically suitable for use as a filling material, as raw material in civil works (quality of the material must be tested prior to any use), or to be left in-situ in a stabilised condition.
Entry criteria	Avoid polluted waste, polluted sorbent and pebbles.
Operational constraints	Requires easily available equipment (e.g. earth moving equipment to mix the quicklime with the polluted material), little personnel, and binding agent (e.g. quicklime). In case of oil content too high or high temperature, there is a risk of fire. The grain size of the bulk quicklime has to be adapted to the grain size of the oiled sediment to treat (the smaller the sediment, the coarser the quicklime, e.g. quicklime grain of 20 to 40mm to treat silt and sand mix).
Impacts	The oxydo-reduction reaction is followed by atmospheric releases of dust, gases and fumes. Leachate of stabilised material has less than 1% of oil (in the worst case). The stabilized material is limited in time, the gradual degradation of the stabilisation process and the release of the remaining contaminants in the environment must be anticipated, when considering the final disposal environment.
Legal constraints	Refer to atmospheric releases legislation (however, special authorisation should be delivered for such work). May require THC and leachate testing, and EIA or legal authorisation.
Efficiency	80 m^3/ day of waste treated with one mechanical shovel and one experienced driver.
Cost	CAPEX/ OPEX: the price for the stabilisation of 1 m3 of waste is approx. 150 to 200 euros per m3 of waste to treat (depending on the local availability of binding agent).

STABILISATION TREATMENT	**Stabilisation - Vitrification**
Description	Vitrification uses heat to melt (at very high temperature, above melting point, e.g. 1,500° to 2,300°C) the waste, then decrease abruptly the temperature to solidify harmful chemicals in a solid mass of glasslike material. It can be applied on soil in-situ (in-situ vitrification or ISV) and ground in a treatment unit (ex-situ).
Waste	Ultimate waste from pollution (e.g. polluted soils, solid waste)
Situation / Potential in the country	Equipment can be imported and installed. Transportable vitrification systems exist.
Interest	Contaminants is stabilized and solidified in a glasslike material, with better long term performance than other solidification means (hydraulic binding agent).
Entry criteria	Complete characterization of the candidate waste stream is essential, before initiating either in-situ or ex-situ vitrification, to determine what glass forms are already present in the waste and what additional glass stabilizers and fluxes need to be added. Debris greater than 60 mm in diameter typically must be removed prior to processing.
Operational constraints	Use, storage, or disposal of the vitrified slag is required. High level of heat/ energy is required.
Impacts	Concerns include the durability of the vitrified waste. Although, vitrified waste, as compared to a grouted or cemented waste form, are expected to be more stable over longer periods due to the corrosion resistance of glass. The heat used to melt the soil can also destroy some of the harmful chemicals and cause others to evaporate. The evaporated chemicals must be captured and treated.
Legal constraints	Related to waste management and disposal (for the glass like material) and to gas emission and treatment during vitrification.
Efficiency	Vitrification is a proven technology that has been employed during various oil spills. However, very high level of energy is required, which leads to high costs.
Cost	OPEX: from 150 to 230 Euros/ ton (Source: KOLLER), depending on the size and capabilities of the installation, to more than 300 Euros/ ton for specific waste.
BIOREMEDIATION TREATMENT	**Bioremediation: enhanced bioremediation <u>In Situ</u>**
Description	Stimulating bioremediation by addition of micro organisms (e.g., fungi, bacteria, and other microbes) and/ or nutrients (e.g. oxygen, nitrates) to the subsurface environment to accelerate the natural biodegradation process by the naturally occurring microorganisms of the soil. Bioremediation can take place under aerobic or anaerobic conditions. There are four major processes, briefly described below. **Bio-Stimulation:** • **Gaseous Nutrient Injection** In this case, nutrients are fed to contaminated groundwater and soil via wells to encourage and feed naturally occurring microorganisms. • **Oxygen Enhancement** with Hydrogen Peroxide as an alternative to pumping oxygen gas into groundwater. • **Nitrate Enhancement** A solution of nitrate is sometimes added to the groundwater to enhance anaerobic biodegradation. **Bio-augmentation** Sometimes acclimated microorganisms are added to the soil to increase biological activity. However, the efficiency of this technique is not as well proven as the bio-stimulation. The first three methods are preferred because they stimulate the naturally occurring indigenous micro-organisms, already adapted to the environment.

Waste	Lightly oiled sediment (sand, gravel, soil, mud). Oiled seaweed and vegetation (even fauna) may be treated
Situation / Potential in the country	May be easily implemented on any polluted site (usually considered for coastal sheltered sites with slow natural clean-up by waves or inland sites).
Interest	• it is relatively inexpensive with low energy requirements • it can be carried out without elaborate equipment
Entry criteria	Oil with a high asphaltene and resin content degrades slowly due to the molecular recalcitrance of the hydrocarbons while oil with a high aliphatic and aromatic content is a much more nutrient-dependent process and will degrade more rapidly within the adequate environment. It is recommended to carry out a GC/ MS analysis to define the composition of the oil and evaluate its biodegradability. To achieve maximum biodegradation, sediment pore water should exhibit concentrations of 1.5 mg nitrate/litre, Phosphorous concentrations of approximately one-tenth of the nitrate levels, with oxygen levels above 2 mg/litre (Source: AMSA). High permeability soils are required to allow the nutrients to reach the indigenous microorganisms (avoid fines clays).
Operational constraints	Easy access to the treatment site. Bio degradation is less efficient at low temperature. Soil must be humid. Pollutants must not be adsorbed to clay and/ or mud. In this case, they are unavailable for the micro organisms.
Impacts	Under anaerobic conditions, contaminants may be degraded to a product that is more hazardous than the original contaminant. Nitrate injection to groundwater is of concern because nitrate is a regulated compound. Bio-augmentation using non-native micro-organisms is also controversial. The circulation of water-based solutions through the soil may increase contaminant mobility and necessitate treatment of underlying groundwater.
Legal constraints	Refer to those applying to the management of polluted soils in situ. Special authorisation should be delivered for such work.
Efficiency	Bioremediation is a long term process (months to year(s)). Bioremediation degrades aromatics, N-alkanes and iso-alkanes. Resins and Asphaltenes are usually resistant to bioremediation. Cyclic hydrocarbons (Saturated and Aromatics) are partially biodegraded. The efficiency of biodegradation can reach satisfactory levels when correctly implemented on biodegradable material.
Cost	Limited, less than 30 euros / m3 (Source: KOLLER), 15 to 75 euros/ ton (Source: Bocard) Related to the manpower, equipment for the spreading and purchase of stimulating agent.
BIOREMEDIATION TREATMENT	**Bioremediation: land farming**
Description	Contaminated soils are mixed with soil amendments such as soil bulking agents and nutrients, and then they are tilled into the earth. The oily debris should be evenly spread over the scarified land surface in a layer 2-10cm thick. Contaminants are degraded, transformed, and immobilized by microbiological processes and by oxidation.
Waste	Semi-solids and solids lightly oiled.
Situation / Potential in the country	May be very easily implemented.
Interest	Allows biodegradation of oily waste with little equipment (requires large area of land away from ground water and human settlements).

Entry criteria	Oil with a high asphaltene and resin content degrades slowly due to the molecular recalcitrance of the hydrocarbons while oil with a high aliphatic and aromatic content is a much more nutrient-dependent process and will degrade more rapidly within the adequate environment. It is recommended to carry out a GC/ MS analysis to define the composition of the oil and evaluate its biodegradability. Lightly oiled sediment (sand, gravel, soil, mud), less than 1 to 2% of oil. Land farming is best suited for debris comprised of small particles such as oiled soils, and should not be attempted for waste comprised of particles larger then 15cm to avoid handling difficulties and problematic mixing of the waste.
Operational constraints	Requires large area of land in a suitable environment: land farming is best suited to warm climates with moderate precipitation and evaporation. The degradation process may stop when temperatures fall below freezing. Regular tilling is necessary for aeration. Sufficient moisture is required in the oil/soil mixture to support microbial activity, which is usually naturally available except in very dry areas. Areas should be located where water bodies and other supplies of potable water are not at risk from the possible release of contaminants. Slope of area should be less than 4% (or else plan for run-off water management). Soil permeability should be low to avoid percolation of leachates into the ground water. Slope should also be low to avoid running. Additions of nitrogen (as ammonium nitrate) and soluble phosphorous (e.g. super-phosphate) are necessary for the degradation of oily wastes at optimum rates. Environmental monitoring is necessary (soil and ground water analysis).
Impacts	Main risk is the contamination of the ground water by percolation of contaminants and running surface water carrying the contaminant away from the land farming area.
Legal constraints	Refer to limits of contaminants that can be spread on land (e.g. regulations related to land farming of mud from sewage water treatment plants). May require EIA or legal authorisation.
Efficiency	Land farming degrades oil into carbon dioxide gas, water and matter within 2 years or less. Bioremediation is a long term process (months to year(s)). Bioremediation degrades aromatics, N-alkanes and iso-alkanes. Resins and Asphaltenes are usually resistant to bioremediation. Cyclic hydrocarbon (Saturated and Aromatics) are partially biodegraded.
Cost	Cost of the equipment is limited (earth moving equipment). However, land farming requires large areas of land (to rent or purchase for years). OPEX: • 5 to 50 Euros / m^3 for the “natural” treatment (without nutriments and/ or enzymes) and without any treatment of leachate. • 20 to 150 Euros / m^3 for the treatment with nutriments or enzymes and without any treatment of leachate (Source: UNDP).
BIOREMEDIATION TREATMENT	**Bio-treatment: composting**
Description	Composting is the biological conversion of organic waste solids into stable, humic material (which contributes to the soil structure as well as its nutritional status). Composting is achieved by mixing with bulking agents and organic amendments, spreading the oily waste in windrow (or other shapes), regular tilling for oxygenation and addition of nutrients. There are three major designs used in composting. • aerobic static pile/ compost is formed into piles and aerated with blowers or vacuum pumps, • use of a vessel similar to a bio-reactor, where the compost is mechanically agitated and aerated, • windrow composting, usually considered the most cost-effective composting alternative.
Waste	Lightly oiled seaweed and vegetation (i.e. biodegradable material), sand may be present
Situation / Potential in the	May be very easily implemented.

country	
Interest	• Recovery of natural resource (sand) • Low cost • Larger quantity will result in economy of scale
Entry criteria	Oil with a high asphaltene and resin content degrades slowly due to the molecular recalcitrance of the hydrocarbons while oil with a high aliphatic and aromatic content is a much more nutrient-dependent process and will degrade more rapidly within the adequate environment. It is recommended to carry out a GC/ MS analysis to define the composition of the oil and evaluate its biodegradability. Usable only for oiled vegetal that are lightly to medium polluted, and should not contain cobble or boulder.
Operational constraints	Requires personnel, expertise, earth moving equipment, nutriments and large surface of ground, particularly for in-situ treatment options. The site must meet hydro-geological and physical requirements. Selection criteria include the following items: • no oil is recovered; • requires a lot of testing, monitoring, foundation and mechanical work; • requires large surface area; • dispersed quantity of contaminated soil increases the cost.
Impacts	Minimal if suitable monitoring and containment program is implemented. But possible increase of VOC (Volatile Organic Compound) emissions, and windrow composting has a high dust emission.
Legal constraints	Refer to waste and oily water / soil legislation.
Efficiency	Composting is faster than enhanced bioremediation on site: process lasts less than one year (may be 3 to 6 months depending on the degree of pollution of the waste). Bioremediation degrades aromatics, N-alkanes and iso-alkanes. Resins and Asphaltenes are usually resistant to bioremediation. Cyclic hydrocarbon (Saturated and Aromatics) are partially biodegraded.
Cost	Costs compare to the cost of land farming (usually less than 50 Euros per ton). However, composting does not require large areas of land and compost can be sold at 15 to 23 Euros per ton (Source: Damien).
BIOREMEDIATION TREATMENT	**Bioremediation: Bio-pile** ("biopile" or "biotertre" in French)
Description	A bio-pile is a bioremediation technology in which excavated soils are mixed with soil amendments, formed into compost piles, and enclosed for treatment. The basic bio-pile system includes a treatment bed, an aeration system, an irrigation/nutrient system and a leachate collection system. Note. Systems known as Bio-Reactors are usually used to treat sewage water. They can also treat oily water, and testing is on going to treat polluted soils with this technique. Contaminated groundwater is circulated in an aeration basin where microbes degrade organic matter, forming a sludge that is disposed of or recycled.
Waste	Oily water Lightly to medium polluted sediment (up to 5% of oil, more depending on installation)
Situation / Potential in the country	Technically easy to implement if land is available on long term basis (few years).
Interest	Bio-pile is a more controlled and efficient treatment than composting, allowing treatment of more oiled sediment and waste. The material may be returned on site once the treatment is completed.
Entry criteria	Oil with a high asphaltene and resin content degrades slowly due to the molecular recalcitrance of the hydrocarbons while oil with a high aliphatic and aromatic content is a much more nutrient-dependent process and will degrade more rapidly within the adequate environment. It is recommended to carry out a GC/ MS analysis to define the composition of the oil and evaluate its biodegradability. Treatability testing should be conducted to determine the biodegradability of contaminants and appropriate oxygenation and nutrient loading rates. Laboratory or field treatability studies are

	needed to identify the best amendments.
Operational constraints	The site of implementation of the biopile depends on the land availability in the area and on the volume of waste to treat (cost of the transport). Testing (in laboratory and on limited quantities) is necessary. Continuous contaminant and environmental monitoring program is necessary (moisture, heat, nutrients, oxygen, and pH).
Impacts	Biogas and leachate must be managed adequately. The treatment area is generally covered or contained with an impermeable liner to minimize the risk of contaminants leaching into an uncontaminated soil.
Legal constraints	Refer to waste and oily water / soil legislation.
Efficiency	Bioremediation is a long term process, although speed is increased in biopile, degradation of resistant oil compound may still take more than 2 years. Bioremediation degrades aromatics, N-alkanes and iso-alkanes. Resins and Asphaltenes are usually resistant to bioremediation. Cyclic hydrocarbon (Saturated and Aromatics) are partially biodegraded.
Cost	Varies depending on the volumes to be treated. Ranges from 60 to 200 euros per tons of waste to treat (if there is less than 100 tons) to 50 to 100 euros per ton (for 1,000 tons or more of waste) including the analysis.

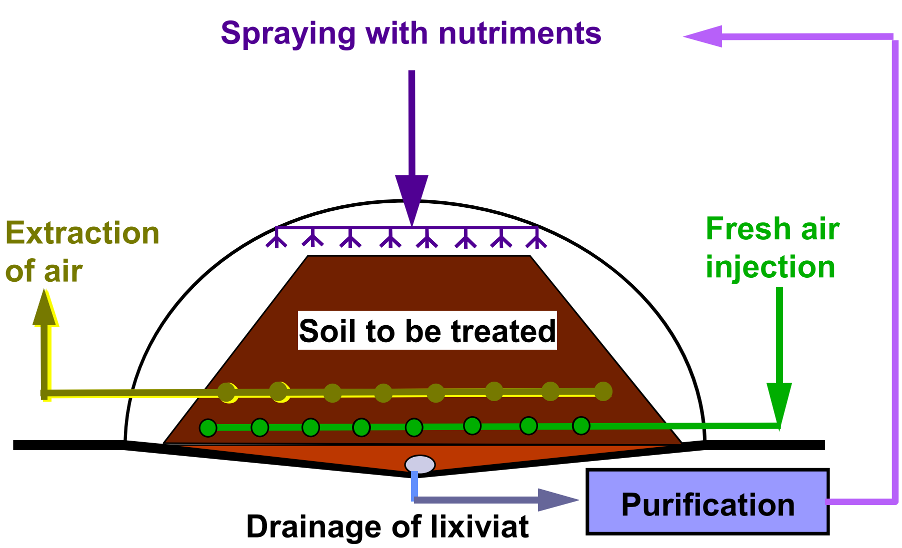
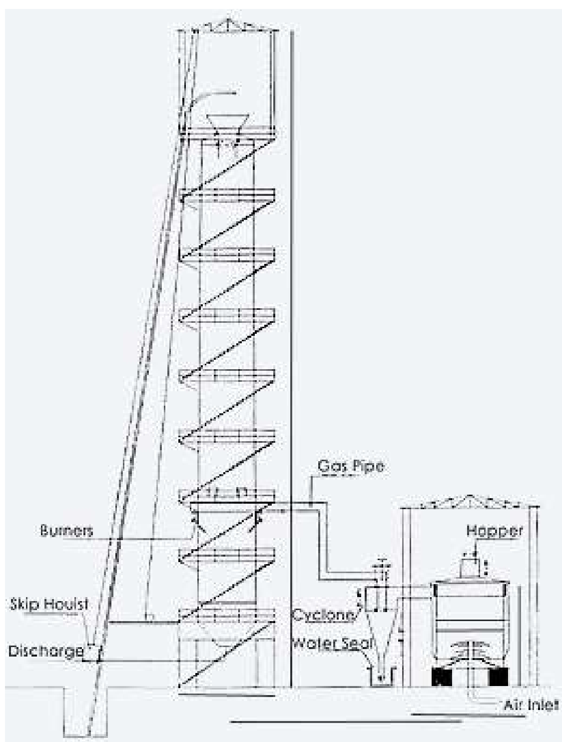


Figure 12 : Conceptual model of a Bio-pile

THERMAL TREATMENT	**Incineration in domestic waste incinerators**
Description	Incineration of the waste in incinerators used for domestic waste.
Waste	Liquid Semi-solids and solid Lightly polluted sorbent Lightly polluted solid waste
Situation / Potential in the country	Some domestic waste incinerators may be technically suited to receive oily waste.
Interest	• Permanent waste elimination. • Could achieve up to 99% volume reduction. • Operated at very high temperature (at 1,200°C), the process is suitable for the destruction of many hazardous air pollutants.

Entry criteria	The list of types of domestic waste that can be treated in the plant is often defined by national regulations. This list may be temporarily and exceptionally enlarged to accept oil spill waste. Domestic incinerators can manage lightly to medium oiled waste, but may not be able to handle heavily oiled waste (which may cause the outbalance of energetic/ thermal balance of the incinerator), except if diluted sufficiently with the "normal waste".
Operational constraints	Domestic waste incinerators are generally not the best suited incinerators since chlorides from sea water leads to corrosion. The oily waste may have to be diluted with the "normal" waste, thus decreasing the treatment rate. Requires personnel, site, incinerator and waste handling equipment. • Treatment rate is limited (oily waste must be diluted with other type of waste). • No energy is recovered. • Air pollution control devices might not be suitable. • Salt in recovered oil could increase corrosion in system.
Impacts	Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and of filter installed on the chimney.
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Relies on the type of incinerator and gas treatment.
Cost	For the construction of a domestic incinerator: CAPEX: high investment cost, OPEX: 100 to 400 euros / m3 (Source: KOLLER), depends on the size and personnel of the installation, and on pre-treatment required.
THERMAL TREATMENT	**Incineration in industrial incinerator or other type of furnace / kiln or power plant**
Description	Incineration of the waste in specialized incinerators used for hazardous waste / industrial waste.
Waste	Any type of waste but mainly used for: Liquids Semi-solids and solid Polluted solid waste
Situation / Potential in the country	Installation that may incinerate oil spill waste: • Industrial incinerator (850° to 1,100°C) • Power plant • Lime kiln (operates at 950° to 1050° C) • Glass industry • Smelting industry
Interest	• Permanent waste elimination. • Could achieve up to 99% volume reduction. • Operated at very high temperature (at 1,200°C), the process is suitable for the destruction of many hazardous air pollutants. • Able to handle waste with hazardous substances (Cl, S, heavy metals, PAH, PCB…).
Entry criteria	Industrial incinerator can accept a wide variety of waste, even heavily oiled (over 30% of oil). Entry criteria depends on the gas and fume treatment capability of the plant. Power plant can accept solid waste (when operating with grill incinerator or fluidized beds). Power plants with fuel burner/ gas burner can accept liquid waste and solid waste (if it is finely shredded). Other kilns have more restrictive entry criteria, e.g. for lime kiln (France): • Size of particle < 10 mm, • Calorific power > 2500 kcal/Kg, • Water content < 30%,

	• Sulphur < 1%, • Total halogens (Cl, Br, F, I) < 1%, • PCB < 100 mg/Kg, and PCT < 100 mg/Kg. The oily waste will be added to the incinerated material in a proportion depending on the composition of the oily waste.
Operational constraints	Requires personnel, site, incinerator and waste handling equipment. • No energy is recovered. • Air pollution control devices must be suited to monitor the incineration of large quantities of petroleum product. • Salt in recovered oil could increase corrosion in system. • If the facility does not exist, this type of project needs a long period to be implemented.
Impacts	Incineration (e.g. in power plants) results in the production of ashes and co-products that must be disposed of correctly. Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and of filter installed on the chimney.
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Relies on the type of incinerator and gas treatment.
Cost	CAPEX: very high investment cost. OPEX: 100 to 400 euros / m3 (Source: KOLLER).
	 **Figure 13 : Lime kiln**
THERMAL TREATMENT	**Co-incineration as fuel source (in cement works, lime kiln, power plant or other kiln)**
Description	Incineration of the liquid oil recovered as fuel source in cement works (and/ or industrial furnaces) Note. Co-incineration is the incineration of waste in industrial incinerators, kilns, furnaces as an alternative or complementary fuel source and/ or as material source.

Waste	Liquid Pasty waste Depending on installation: solid waste
Situation / Potential in the country	Some cement facilities have special adaptations to receive OSW as fuel.
Interest	Liquid : • Recovery and re-use of oil as valuable energy source • Cost recovery option
Entry criteria	Waste has to meet stringent technical specifications: • heavy metals, mercury, MgO and zinc (e.g. less than 1%), • chlorine (e.g. less than 2%), • sulphur (e.g. less than 4%), etc. • (Possible reference to the Stockholm Convention). The kiln operator will evaluate the calorific power of the waste, minimum of 2,500 to 3,000 kcal/ kg is required. Additional monitoring requirements will be required by the kiln operators regarding sulphate, alkalin, and solid residue content. ➔ Some cement kilns have restrictive criteria: • no sand, • dry residue: 2% maximum, at 90 microns maximum, • no (or very little) chlorine), • plastic is possible but no PVC or chlorine. Pre treatment is often needed.
Operational constraints	Waste must be homogeneous and of a controlled and quantified calorific power. Requires personnel, site, incinerator and waste handling equipment. • salt in recovered oil could increase corrosion in system; • depends on the installations (i.e. burners and injectors); • content in chlorine and sulphate must be limited; • requires **pre-treatment** (processing and screening) which is labour intensive; • quality of oil recovered could be a limiting factor.
Impacts	Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and of filter installed on the chimney. ➀ **See the Appendix** “Emission limits for co-incineration in cement kilns”, p.109
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Depends on the substitution rate : from 1 to 1.5 tons/ day
Cost	CAPEX: use of already existing installation, may require adaptation to handle oil spill waste. OPEX: Estimated to 30 to 50 Euros/ ton (may be 0 euro if oil does not need pre-treatment), depending on the quality of the recovered oil and on the additional cost for waste pre-processing in the plant (demulsifying, screening for absence of heterogeneous elements etc.)
THERMAL TREATMENT	**Co-incineration as raw alternative material (in cement works or other)**
Description	Incineration of polluted sand and solid waste in cement works as Alternative Raw material (Sand is a natural raw material consumed in cement production).

	Note. Co-incineration is the incineration of waste in industrial incinerators, kilns, furnaces as an alternative or complementary fuel source and/ or as material source.
Waste	Polluted sand Polluted solid waste
Situation / Potential in the country	Some cement facilities have special adaptations to use OSW (sands, muds, solid waste) as raw material.
Interest	• Contaminated solid waste (woods, plastic, and other macro-waste) could be processed in kiln as Alternative Fuel and Raw material. • Final elimination of contaminated sand and of most solid waste material. Previous successful experience in Holcim France for treatment of waste generated from Erika spill (Source: Holcim Europe direct communication).
Entry criteria	➔ Depending on each facility: • Sand may be processed; • No pebbles is allowed in the system; • Plastic is possible but no/ very little PVC or chlorine. The kiln operator must maintain an overall waste composition comprising: • $Si\,O_2$: 21 to 24%, • $Al_2\,O_3$: 4.5 to 6%, • $Fe_2\,O_3$: 3 to 4%, • Ca O : 64 to 66%.
Operational constraints	The content of oil in the waste must be limited to avoid outbalancing the energetic balance of the kiln (e.g. waste must have less than 0.5% THC in France) Requires personnel, site, incinerator and waste handling equipment. • salt in recovered oil could increase corrosion in system; • should be free of mercury, zinc, MgO and ferrous metals as it effects kiln operation; • potential change in emission characteristics due to waste characteristics; • require **pre-processing** which is labour intensive.
Impacts	Loss of natural sand resources. Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and of filter installed on the chimney. **See Appendix** “Emission limits for co-incineration in cement kilns”, p.109
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Depends on the substitution rate : from 1 to 5 tons/ day
Cost	OPEX: from 30 to 150 Euros / ton according to waste condition. Mostly no additional cost if lightly contaminated soil with oil and solid waste (Source: Holcim Europe direct communication)
THERMAL TREATMENT	**Thermal Desorption** (Low Temperature Thermal Desorption LTTD)
Description	Thermal desorption separates contaminants from soil. Soil is heated in a chamber in which water, organic contaminants and certain metals are vaporized. A gas or vacuum system transports vaporized water and contaminants to an off-gas treatment system (the design of a system aims to volatize contaminants, while attempting not to oxidize them; otherwise, thermal desorption would be another way of saying incinerator). It is important to note that thermal desorption does not destroy organic compounds. Based on the operating temperature, this process is categorized into two groups. In **Low Temperature Thermal Desorption (LTTD),** wastes are heated to between 90° and 320°C. LTTD is most often used for remediating fuels in soil. Unless heated to the higher end of the LTTD temperature range, organic components in the soil are not damaged, which enables

	treated soil to retain the ability to support future biological activity. In **High Temperature Thermal Desorption (HTTD),** wastes are heated to 320° to 560 °C. HTTD is not used for oil/ fuel contaminated soil treatment.
Waste	Polluted soil, sand and often small pebble (e.g. no larger than 5cm)
Situation / Potential in the country	Equipment can be imported and installed.
Interest	• Very effective in reducing concentrations of petroleum products including gasoline, jet fuels, kerosene, diesel fuel, heating oils, and lubricating oils.
Entry criteria	• Applicable to constituents that are volatile at operating temperatures.
Operational constraints	Requires personnel and expertise to operate, site, waste transport and handling equipment. • Treatment of the off-gas must remove particulates and contaminants. • Dewatering may be necessary to achieve acceptable soil moisture content levels. • Technique developed for soil remediation (not accidental pollution treatment), applicability for OSW depends on the characteristics and on the hydrocarbon content of the waste. • THC concentration should be maximum 3% (except for systems operating in an inert atmosphere e.g. thermal screw). System is not suited for high concentrations of oil in waste (e.g. 20 to 30%). • Due to the low temperature used, it is probable that weathered oil generally recovered on beach will not be treated (would require higher temperature to evaporate).
Impacts	Minimal, if the vaporized hydrocarbons are correctly treated in a secondary treatment unit: afterburner, catalytic oxidation chamber (which destroys the organic constituents), condenser, or carbon adsorption unit (which trap organic compounds for subsequent treatment or disposal) prior to discharge to the atmosphere.
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	• Rapid treatment time; most commercial systems capable of over 25 tons/ hr throughput. Thermal screw: up to 15 tons/ hr. • Can consistently reduce THC to below 10 ppm and BTEX below 100 ppb (and sometimes lower).
Cost	Total cost of treatment for one m3 ranges from 40 to 200 euros / ton (Source: Bocard) Typical cost for oily waste treatment is approx. 150 euros (Source: Cedre)
THERMAL TREATMENT	**Incineration in mobile incinerators**
Description	Incineration of the waste in mobile incinerators.
Waste	Liquid Semi-solids Oiled seaweed and vegetation Solid waste
Situation / Potential in the country	May be easily implemented in the country.
Interest	Complete incineration of the waste.
Entry criteria	Some plastic and metal may cause problem (e.g. sorbent, gloves, complex plastics etc.). Sand, gravel and stones will not be incinerated.
Operational constraints	
Impacts	Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and the filter installed on the chimney.

	ⓘ **See Appendix** "Example of incinerator gas release", p.110
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Modern incinerators are efficient and allow treating on site the gas.
Cost	Highly variable depending on the size, capabilities and emission treatment capabilities of the incinerator.
THERMAL TREATMENT	**Burning of lightly oiled vegetation (open air)**
Description	Burning on site of vegetation (i.e. wood) lightly oiled.
Waste	Lightly oiled vegetal waste
Situation / Potential in the country	
Interest	Permanent elimination of oiled vegetal waste.
Entry criteria	Vegetation must be lightly oiled to avoid atmospheric releases of burnt HC.
Operational constraints	Requires adequate site, and personnel. Burn vegetation away from any sensitive areas, houses, etc. Ensure that fire is controlled.
Impacts	Limited if only vegetation such as wood is burnt.
Legal constraints	Refer to legislation related to burning of vegetation and atmospheric releases (open air burning of waste is often prohibited, but may be tolerated in emergency cases, for remote locations or islands for example). Specific authorisation may be delivered.
Efficiency	Allow reducing the volume of vegetation and wood by 80 to 90%. Ashes may be dispersed in fields.
Cost	CAPEX: none required. OPEX: limited to the operators.
THERMAL TREATMENT	**Evapo-incineration**
Description	This technique combines incineration and physico-chemical treatment. It involves thermal cracking, during which the aqueous phase of the oil-water mixture vaporises: • Water evaporates (water in the vapour phase is treated by high temperatures in order to remove the residual organic phase). • An oil condensate forms that can easily be incinerated.
Waste	Liquid waste (Oily water, oil with water)
Situation / Potential in the country	May be implemented in the country.
Interest	Complete elimination of the waste.
Entry criteria	Can manage solid waste and sediment.
Operational constraints	Depends on the type of machine used.
Impacts	Minimal when processes are well managed and monitored regularly.
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	High with latest installation.
Cost	CAPEX: very high if no existing installation. OPEX: to define depending on installation.
	75 to 300 euros / m3 (Source: Koller)

THERMAL TREATMENT	**Pyrolysis**
Description	Pyrolysis is a form of incineration that chemically decomposes organic materials in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430 °C (as opposed to incineration and co-incineration which use oxygen so it oxidizes bulk quantities of waste that may be in liquid and solid phase). Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, or fluidized bed furnace.
Waste	Semi-solids and solid Polluted sand
Situation / Potential in the country	There are little installations available (recent technology).
Interest	Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. These co-products can be re-used (as energy or material).
Entry criteria	The technology requires drying of the soil prior to treatment. Particulate removal equipment is also required.
Operational constraints	Depends on the type of equipment used.
Impacts	Pyrolysis results in the production of solid residues (char), liquid residue (oil/ water) and gases that must be disposed of adequately. Incinerators may release carcinogenic and toxic chemicals, including heavy metals, partially-burned organic material such as polyvinyl chloride (PVC), and other organic chemicals, including polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. The concentration of the release depends on the type of waste, of incinerator and the filter installed on the chimney.
Legal constraints	Refer to incineration and atmospheric releases legislation. Special authorisation may be required for such work.
Efficiency	Pyrolysis is still a recent technology. First tests have proven the efficiency of the system.
Cost	CAPEX: very high if no existing installation. OPEX: to define depending on installation.
	75 to 300 euros / m3 (Source: Koller)
FINAL DISPOSAL	**Re-use of oil in refinery**
Description	Re-use of oil in refinery.
Waste	Oil (recovered and treated)
Situation / Potential in the country	Depends on the reception/ installation of the refineries in country.
Interest	Re-use of the oil as fuel.
Entry criteria	Oil must be compliant with the specific criteria of the refinery.
Operational constraints	Requires personnel, transport equipment and oil handling/ transfer equipment.
Impacts	None additional to those of the refinery.
Legal constraints	Depends on local regulations for refining oil.
Efficiency	Complete.
Cost	CAPEX: use of existing refineries. OPEX: limited to the handling of the oil and integration into oil production circuit of the refinery.
FINAL DISPOSAL	**Return of clean sediment on site**
Description	Return on the beaches of sediments (sand and pebbles) to limit the erosion.
Waste	Clean to lightly polluted sand and pebbles
Situation /	

Potential in the country	
Interest	• Limits the coastal erosion. • Diminishes the volume of waste to dispose of.
Entry criteria	Sediment must be clean to be returned on the beaches (however, sediments will continue to be cleaned in exposed areas by the action of the waves, see "surfwashing"). There are no general rules for the return of the sediments on site. Each situation will be studied on a case by case basis by the National Authorities. Example of ERIKA oil spill in France: the threshold was set at 2,500ppm for the cleaned sediments.
Operational constraints	Requires personnel, transport equipment and earth moving equipment.
Impacts	None for clean to very lightly oiled sediments.
Legal constraints	None.
Efficiency	Complete.
Cost	CAPEX: no specific equipment required. OPEX: hire existing equipments and personnel.
FINAL DISPOSAL	**Discharge in natural environment**
Description	Discharge of water following decantation of washing effluents from operations (washing of solid waste, high pressure clean-up of pebbles, etc.)
Waste	Recovered oil (from decantation) Treated washing effluents (from washing operations)
Situation / Potential in the country	During clean up operations, it is usually tolerated that recovered water (from the oil and water mix) is discharged directly in the sea, after decantation in decantation tanks. This discharged water will have very little to insignificant impact compared to the ongoing oil spill. During waste treatment, more restrictive threshold value must be in force (as time and equipment should be available to treat adequately effluents): • concentration for discharge at sea, • daily volume limit for the discharge at sea.
Interest	Avoids the treatment of lightly to very lightly polluted sea water resulting from clean-up operations.
Entry criteria	HC content of the discharged water must not exceed certain amount – to be validated by the National Authorities.
Operational constraints	Water must not be discharged close to sensitive areas. Check the HC content of the discharged water.
Impacts	None if HC content is low.
Legal constraints	Refer to legislation related to coastal water quality. Specific authorisation may be delivered.
Efficiency	Complete.
Cost	CAPEX: none. OPEX: none (related to the cleaning operations).
FINAL DISPOSAL	**Land filling (controlled containment in specialized cells and/ or landfills)**
Description	Storage in landfills or specialized industrial waste storage or specialized cells. Oil spill debris can also be incorporated into an active landfill along with municipal refuse or industrial wastes. Co-disposal with domestic waste may also be considered. Oil can biodegrade slowly with the domestic waste and also remains absorbed by all type of domestic waste, with little tendency to leach out. "*As a general guide, oily waste should be deposited on a top of at least 4m of domestic refuse either in surface strips 0.1m thick or in silt trenches 0.5m deep to allow free drainage of water. The oily material should be covered by a layer of soil followed by a minimum of 2m of domestic waste to facilitate degradation* (...)". Source: IMO. Burial is another landfilling option. Oil spill debris is deposited into pits, trenches or other

	depressions prepared for debris disposal onsite. The excavated soil is used as intermediate and final cover of the debris.
Waste	Liquid Semi-solids and solid Polluted sand and pebbles Polluted sorbent Polluted solid waste
Situation / Potential in the country	Landfills are present in all countries. However, only controlled landfills must be considered.
Interest	**In landfills:** • May be suitable for disposal of lightly oiled waste, which is usually mixed with domestic at a 1 to 5 % ratio, to allow biodegradation of the oil. • Most cost effective solution. **In specialized OSW cells** (industrial landfill) • Depends on the type of storage that could be implemented.
Entry criteria	**In landfills:** • Landfills usually have strict and precise entry criteria. They can be adapted by the authorities: e.g. waste with less than 5% oil contamination. • Restriction on acceptance of oil solid waste types. **In specialized OSW cells**. • Depends on the type of storage and national regulation.
Operational constraints	Requires personnel, specific site, transport equipment, weatherproof containers and cover layer, etc.: • subject to stringent long term monitoring; • will not permanently eliminate the waste; • medium-long period for implementation; • potential higher cost for land filling of oil waste compared to normal domestic waste disposal cost.
Impacts	Leachate and biogas must be managed adequately. Limited if safe storage is implemented with a monitoring program (to avoid potential release of toxic compounds). However, landfills <u>do not lessen the toxicity, mobility or volume of waste</u>: they only control migration.
Legal constraints	Requires agreement of the National Authorities.
Efficiency	Complete if safe storage is used.
Cost	In controlled landfills: 75 to 270 euros / m3 (for French installation, Source: Koller), 100 to 300 euros/ ton (Source: Bocard)
FINAL DISPOSAL	**Re-use as road work material**
Description	Re-use of treated material as road fill or construction material.
Waste	Stabilized material
Situation / Potential in the country	No specific requirements.
Interest	Reduces the demand on raw material needed for construction efforts if non-hazardous can be reused.
Entry criteria	Characteristics of material output to be ascertained.
Operational constraints	Personnel, energy, consumables, place, installation, etc.
	If test reveals hazardous material, then the material cannot be re-used: • Requires pre-processing; • Cost of raw material might be cheaper than cleaning of contaminated sand.
Impacts	Mishandling could result in offsite contamination.
Legal constraints	Refer to legislation regarding the characteristics of construction/ filling material (physical, chemical, geotechnical).

Efficiency	Complete
Cost	None if waste is usable on a “as is” basis.
FINAL DISPOSAL	**De-ballasting station**
Description	Facilities where oil tankers can berth and unload their washing waters from their tanks. These waters are then treated in the deballasting station by decantation often using API basin allowing skimming of the oil in surface and recovery of the settled sediment before discharging the water.
Waste	Liquid oily water (if not too weathered or emulsified and with no waste or no sediment) Washing effluents (from washing operations)
Situation / Potential in the country	Depends on installation that may be present in the country.
Interest	Allows treating oily washing effluents and/ or oily water in a controlled environment before discharging in the environment.
Entry criteria	Must be liquid waste.
Operational constraints	Limited capacities Recovered oil is routed to oil refineries. Water is discharged after treatment in the environment.
Impacts	Minimal when processes are well managed and monitored regularly.
Legal constraints	Refer to legislation regarding waste management.
Efficiency	High with latest installation.
Cost	CAPEX: high if no existing installation. OPEX: to define depending on installation.