Environmental Accidents
Emergency Response Guide II

POLLUTION CONTROL TECHNIQUES

SUMMARY

RIVER SHIELD 5D189

INTERREG III B CADSES

INTERREG IIIB CADSES

CONTENTS

1 Preface

This Emergency Response Guide to environmental accidents was compiled in the framework of the "River-Shield" project, which is co-financed by the INTERREG IIIB CADSES program under the reference number 5D189.

The project's objective is the protection of rivers from accidental industrial pollution. It is implemented in cooperation of environmental associated bodies from Greece, Hungary, Poland, Czech Republic, Slovenia and Bulgaria. River-Shield is consisted of experience exchange, know how transfer and dissemination activities. During this process outputs like: good practice guides, and conclusion reports are created. The main project activities and deliverables are presented at the www.rivershield.org web page.

Three emergency response guides for accidental industrial pollution that threatens mainly river areas were created. The first one is about emergency Preparedness and Response, the second about special Pollution Control Techniques and the third about Operational Support. This particular guide is mainly about pollution control techniques of oil spills, which are among the most common environmental accidents. Hydrocarbon fuels represent 40% of the dangerous substances of high priority according to EU industrial safety legislation (SEVESO II directive). Other dangerous substances undiluted in water can be treated with similar practices. Methods for the treatment of various different (inorganic, radioactive, explosive...) substances are presented at the appendix.

Pollution Control techniques are divided to those which are implemented just after the realization of the incident and aim to its containment and to those that follow and aim to the minimization of its consequences and to the remediation of the environment. They are subcategorised further according to the type and place of the contaminated area.

Whatever is mentioned in the guides and in through all the project activities represent the views of the River-Shield partners and not in any way of the European Commission which only co-finances the project.

2 Pollution Control in Surface Waters

Oil spill in moving waters results to the quick expansion of the pollution and to the escalation of environmental consequences. Therefore it is critical to:

- Acquire the appropriate means for oil spill containment
- Promptly implement the right pollution control techniques

The first response activities include the selection of the appropriate pollution control technique and of the place of intervention. Both the selected technique and place should facilitate the future collection of the pollutant. Therefore the following parameters should be considered:

Place Selection

- Characteristics of the surface waters, depth, width, and velocity
- Ease of access for personnel and technical means and resources
- Sensitivity of the surrounding environment and protective legislation

Slow moving, calm water current is more convenient than a fast moving turbulent one. Therefore it is preferred to place the barriers at a wide part of the river with low speed, than at a narrow point with high speed.

Technique Selection

Fixed or /and floating barriers are mostly used for the confinement of oil spill expansion. According to the depth, width and velocity of the water the appropriate barrier is used.

Characteristics of Water Receptor			**Type of Barrier**
Depth	**Width**	**Water Velocity**	
< 0.5 m	any width	any velocity	Fixed
0.5 - 1 m	≤ 5 m	≤ 0.5 m/sec	Fixed or /and Floating
> 1 m	> 5 m	0.5 - 1.5 m/sec	Floating

Fixed Barriers are easily constructed by materials like:

- Bags of soil or sand that are piled one on the top of the other at the bottom of the water receptor
- Parcels of straw that are put in two parallel lines vertically one another
- Wooden surfaces and beams that are put on the bottom of the river and opposite to its flow
- Nets of absorbing material from the one bank to the other that are stabilised with beams at the banks and to the bottom of the river.

They are used when the depth is limited and smaller than 5m. They are subdivided to those that permit water flow and to those that they do not. The latter are easier to be constructed but they result often in oil spill over. Therefore they are only used when water flow is limited. All fixed barriers require salad installation and frequent inspections of their condition.

Floating Barriers aim to the confinement of the pollutant existing on the surface of the running water. They are pre-constructed and exist in various shapes and sizes. They can be used for the re-direction of the pollutant's flow, for the protection of a sensitive area (exclusion booming) and for the removal of the pollutant from a certain area (diversion booming).

The installation of a floating barrier causes the increase of the water flow and respective turbulence. This increases the mixing of oil with water causing the escape of some oil. This phenomenon can be minimized by limiting the immersion of the barrier to 20% of the river's depth.

The installation of the floating barriers is selected according to the velocity of the river flow. Vertical installation is used in velocities smaller than 0.3 m/sec. Angle installation is used in velocities between 0.3 and 1.2 m/sec, which help in the water speed reduction and to the direction of the pollutant to the collection bank of the river. Usually two subsequent, floating, in angle barriers are installed. V-shape installation of barriers is used when the water velocity is greater than 1.2 m/sec. The required length of the barrier in this case is at least 4 times the width of the river. In this case the removal of the pollutant from both the banks of the river should be possible.

3 Pollutant Removal from Surface Waters

The pollution control techniques are followed by pollutant removal techniques, which are implemented in two steps:

1. Removal of the heavy layer of oil from the surface of the receptor.
   a. Use of skimmers in large width rivers with the combination of floating barriers.
   b. Use of pumps which suck the oil from the surface of the water when the flow is slow and calm.
2. Removal of the thin layer of oil from the surface of the water, with the use of natural or artificial absorbing materials like: straw, flakes of wood, dry leaves or special petrochemicals like polypropylene and foam of polyurethane. These materials are spread on the remaining oil spill and collected afterwards with ordinary tools.

Skimmer selection is made according to the characteristics of the water receptor, the viscosity of the pollutant and the specific operating parameters of the skimmer.

- Oil-detaining skimmers have brushes, disks, ropes, etc, made of materials that detain the pollutant. Afterwards the pollutant is removed from the oil-detaining surface and stored. They can be efficient in small layers of pollutants and in streams with debris.
- Weir type skimmers operation is based on a small adjustable barrier that permits the flow of the oil above a verge to a collection tank. It is mounted on a floating device which is lifted by a crane that is usually manually operated. They can be easily and efficiently used in pollutants with various viscosities.
- Hydrodynamic skimmers use either hydro-cyclones of natural flow or forced flow devices of the water oil mixture. The operation is based on the adjustment of a plate that drives the oil above the water, where it is removed.

- Rope skimmers use moving zones of absorbing materials while belt skimmers use fins which collect oil by operating in angle. The removed oil water mixture is stored in precipitation tanks, where oil is finally removed from the surface. These skimmers are efficient in high water velocities. In rivers with depth smaller than 0.3 m rope type skimmers are suggested.

There are various types of sucking **Pumps**: rotating – centrifugal, cochlear, piston-bearing and diaphragm. The selection of the most appropriate device is based on the type of the water receptor, the oil viscosity, the presence of debris, the creation or not of oil water emulsion and the specific operating characteristics of the pump.

4 Remediation of River Banks

The selection of the appropriate remediation technique is depended on:

- Health and safety considerations for the involved personnel.
- River bank materials, existence of rocks, stones, type of soil, etc.
- Amount of the accumulated oil.
- The depth of oil penetration to the banks.
- The accessibility for both personnel and equipment.
- The ecological sensitivity of the area.
- The current weather conditions.

The remediation process begins with the removal of the heavy and standing oil. It is followed by the cleaning of the area and of the materials that have been covered by oil. Finally the light traces of pollution are removed. The remediation methods include physical, biological and chemical techniques.

Physical techniques include: Natural Degradation which is used when accessibility is difficult and other techniques may cause more serious problems; Use of Absorbing Materials which is efficient when oil has not stack on other surfaces; Manual Removal of polluted materials when pollution is limited; Use of Special Vehicles for sand and shingle shores; Cutting and removal of contaminated plants; Wash down with low pressure, warm water in rocky and stony shores; Wash down with high pressure water in rocks, stones and man made structures; Suction with vacuum tanks when oil is standing; Use of Manual Tools when pollution is limited and no other technique is applicable; Earthmoving Machines when accessibility is feasible and extensive removal of materials is necessary; Sandblast for the removal of oil films from hard surfaces; Burning when there are sufficient quantities and no heavy oils or emulsions, this process should be closely monitored. In most cases physical methods present low environmental consequences and are the most common remediation techniques applied.

Chemical techniques can be used only with the approval of the competent public authorities. There are two types of chemical substances that can be used as cleaners, Hydro-dissolvable which are dissolved in the cleaning water and Non hydro-dissolvable solvents which are used 15 to 30 minutes before the water wash. The selection of the appropriate chemical is based on the ability to collect the wastes of the washing. However the use of chemicals is considered as the last washing alternative.

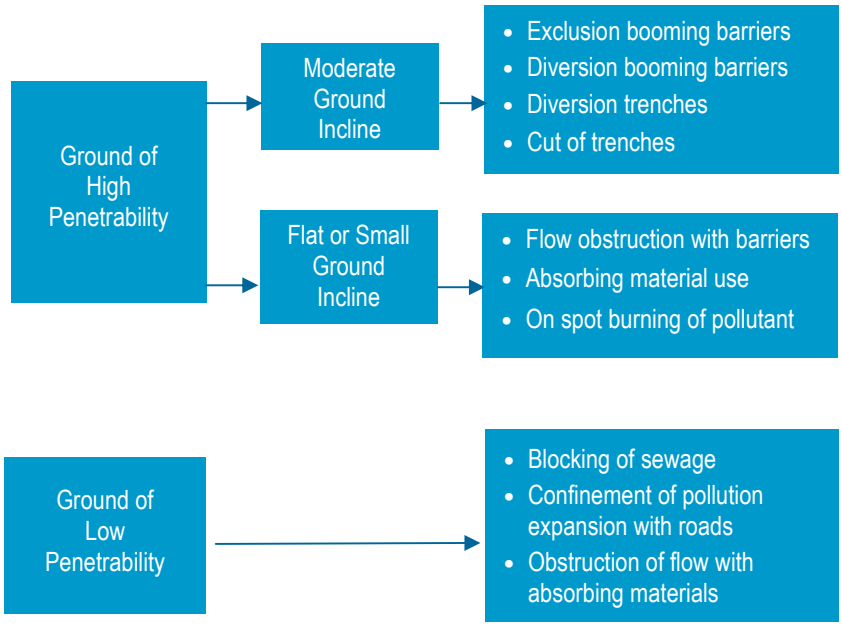
Biological techniques are usually used during the final stage of the remediation, since their application is not feasible in standing oil or in bulks of tar. This method is implemented when oil remains at the area without being washed down by nearby waters. Two types of fertilizers are used: Oil-detaining liquid materials, which are spayed to the area after being heated to approximately 30^0C in order to flow easier and Nutrient substances in the form of pellets, which are poured to the polluted area, either by hand or with appropriate gardening equipment. The pouring of the fertilizers is repeated according to the type of the pollution and of the fertilizer. Their environmental consequences are low if the appropriate application is used. Biological methods are applied when other techniques cannot be used.

5 Pollutant Collection from the Ground

In an industrial accident pollution may threaten water receptors and the ground. In both cases pollution must be controlled. Parameters like the type of terrain, the incline of the ground, the volume of the release play a key role in the design of the appropriate response operation. The main objectives of the response operation are:

- Immediate response and confinement of the release near the source.
- Health and safety of personnel and Minimization of fire probability.
- Obstruction of pollution from surface or underground waters or other sensitive environmental receptors or sewage installations.
- Protection of the environment and nearby infrastructures.

Pollution Confinement techniques include methods that concentrate the pollutant in a confined area, which has been appropriately modulated for this purpose. The graph bellow presents general guidance.



The efficiency of the above methods is impeded by the accessibility to the site, the required time for application, the rough and rocky terrain, the environmental consequences of excavations and the presence of natural water flow.

Pollutant Collection techniques include the use of machinery and equipment for the excavation and removal of the contaminated soil, the collection of standing oil with vacuum tanks, pumps and skimmers, the absorption of the pollutant with artificial or natural materials, the wash down of the ground with water under pressure and the flooding of the area with water to make the pollutant float above.

The application of these techniques can have significant environmental impacts like: disturbance of area flora and fauna, production of large quantities of wastes (contaminated soil, waters, absorbing materials), direction of the pollution to areas not previously threatened. Therefore collection techniques should be selected and implemented in caution.

6 Cleaning and Remediation of Sub-ground

The pollution of the subsoil can be caused either by the vertical penetration of the pollutant from the surface, or by contaminated under ground waters, or by leaks of underground pipelines. In the first case pollution control and remediation techniques should be firstly applied.

Land Farming or Land Treatment is used for the decrease of the pollutant's concentration through biodegradation. It is simple in application, low cost, efficient for organic substances with low biodegradation rates and requires small time for application, between 6 months and 2 years under optimum conditions. However it requires extensive areas for implementation. The presence of heavy metals may prohibit the development of micro-organisms. Volatile substances tend to evaporate than biodegrade during the process. Its application may lead to air pollution from vapors and dust and it may require the construction of impenetrable sub layer to stop the escape of oil.

Bio Piling is a process similar to land farming used in excavated ground. It presents the same advantages and disadvantages with land farming but it requires less space for application. Reductions greater than 95% are difficult to be achieved though especially when oil concentration is high.

Bio Venting supports the function of microorganisms that already exist in the ground by supplying air to them. It requires small time for application, ordinary easy to install equipment, can be used in areas with difficult accessibility and it is relatively low cost. High oil concentrations can be toxic to the existing microorganisms. It cannot be implemented in soils of low penetrability. It can be applied only at the zone between the soil and the underground water. Its efficiency is sometimes limited and complementary measures are often necessary.

The implementation of all the above techniques leads to the production of some oil wastes and to inhomogeneous results due to the variety of the ground characteristics of the contaminated area. The selection of the most

appropriate technique can be supported through the discrimination of the following cases.

Case 1: The distance between the front of the pollution that has penetrated the soil and the level of the underground water is less than 1m. Land farming is applied when substantial space exists or Bio piling when respective space is limited.

Case 2: The distance between the front of the pollution that has penetrated the soil and the level of the underground water is between 1 and 3 m. Bio venting technique is used through the construction of injection wells.

Case 3: The distance between the front of the pollution that has penetrated the soil and the level of the underground water is greater than 3 m. Implementation of the Bio venting technique through the construction of deep extraction wells.

In general soil with oil concentration higher than 50.000 PPM should be excavated and removed regardless the applied biodegradation technique.

7 Appendix

Pollution Treatment Techniques Matrix

	Nonhalogenated VOCs	Halogenated VOCs	Nonhalogenated SVOCs	Halogenated SVOCs	Fuels	Inorganic Substances	Radionuclide Substances	Explosive Substances
Soil, Sediment, Bedrock and Sludge								
On site Biological Treatment								
Bio Venting	✓✓	~	✓✓	X	✓✓	X	✓✓	X
Enhanced Bioremediation Aerobic / Anaerobic	✓✓	✓✓	✓✓	~	✓✓	✓✓	✓✓	✓✓
Plant Remediation	✓	✓	✓	~	✓	✓	X	X
On site Physical and Chemical Treatment								
Chemical Oxidation	✓	✓	X	✓	X	~	X	✓
Electric Separation	✓	✓	✓	✓	X	✓✓	✓	X
Fracturing Enhancements	✓	✓	✓	✓	✓	X	X	X
Soil Flushing	✓✓	✓✓	✓	✓	✓	✓✓	X	X
Soil Vapor Extraction	✓✓	✓✓	X	X	✓✓	X	X	X
Solidification / Stabilization Chemical / Cement based	X	X	✓	✓	X	✓✓	✓✓	X

On site Thermal Treatment								
Thermal Treatment	✓✓	✓✓	✓✓	✓✓	✓✓	X	X	X
Off Site Biological Treatment								
Bio Piling	✓✓	✓✓	✓	~	✓✓	~	X	X
Composting	✓	✓	✓	~	✓✓	X	X	✓✓
Land Farming	✓	✓	✓✓	✓	✓✓	X	X	~
Slurry Phase	✓	✓✓	✓✓	~	✓✓	~	X	✓✓
Off Site Physical and Chemical Treatment								
Chemical Extraction Acid / Solvent	✓	✓	✓✓	✓✓	✓	✓✓	✓	X
Chemical Oxidation	✓	✓	✓	✓	✓	✓✓	X	✓
Dehalogenation	X	✓✓	X	✓✓	X	X	X	✓
Separation Magnetic / Physical	✓	✓	✓	✓	X	✓	X	X
Soil Washing	✓	✓	✓	✓	✓	✓	X	X
Solidification / Stabilization	X	X	✓	✓	X	✓✓	✓✓	X
Off Site Thermal Treatment								
Hot Gas Decontamination	X	X	X	X	X	X	X	X
Incineration	✓✓	✓✓	✓✓	✓✓	✓✓	X	X	✓✓
Open Burn / Open Detonation	X	X	X	X	X	X	X	✓✓
Pyrolysis	✓	✓	✓✓	✓✓	✓	X	X	X
Thermal Adsorption High / Low temperature	✓✓	✓✓	✓✓	✓✓	✓✓	X	X	✓✓

Containment								
Landfill Cap	✓	✓	✓	✓	✓	✓	X	✓
Landfill Cap Alternatives	✓	✓	✓	✓	✓	✓	X	✓
Other Treatment								
Excavation, Retrieval and Off-site Disposal	✓	✓	✓	✓	✓	✓	X	✓
Ground Water, Surface Water and Leachate								
On Site Biological Treatment								
Enhanced Biodegradation	✓✓	~	✓✓	~	✓✓	~	X	✓
Natural Attenuation	✓✓	✓	✓	✓	✓✓	X	X	X
Plant Remediation	✓	✓	✓	✓	✓	~	X	X
On Site Physical and Chemical Treatment								
Air Spraying	✓✓	✓	✓	✓	✓✓	X	X	X
Bio Sslurping	✓	✓	✓✓	✓✓	✓✓	✓	X	X
Chemical Oxidation	✓	✓	X	✓	X	~	X	✓
Directional Wells	✓	✓	✓	✓	✓	✓	X	✓
Dual Phase Extraction	✓✓	✓✓	✓✓	✓✓	✓✓	X	X	X
Thermal Treatment	✓	✓✓	✓✓	✓✓	✓✓	X	X	X
Hydro Fracturing Enhancements	✓	✓	✓	✓	✓	✓	X	✓
In-Well Air Stripping	✓	✓	✓	X	✓	X	X	X
Passive / Reactive Treatment Walls	✓✓	✓✓	✓✓	✓✓	✓	~	X	✓✓

Off Site Biological Treatment								
Bio Reactors	✓✓	✓✓	✓✓	~	✓✓	X	X	✓✓
Constructed Wetlands	✓	✓	✓	~	✓	✓✓	X	✓✓
Off Site Physical and Chemical Treatment								
Adsorption / Absorption	✓	✓	✓	✓	X	✓✓	~	X
Advance Oxidation Processes ·· UV Photolysis ·· UV Oxidation	✓✓	✓✓	✓✓	✓✓	✓✓	~	~	✓✓
Air Stripping	✓✓	✓✓	X	X	X	X	X	X
Granulated Activated Carbon	✓✓	✓✓	✓✓	✓✓	✓✓	~	X	~
Ground Water Pumping	✓	✓	✓	~	✓	✓	X	✓
Ion Exchange	X	X	X	X	X	✓✓	✓	X
Precipitation / Coagulation / Flocculation	X	X	X	X	X	✓✓	✓	X
Separation Distillation / Filtration Crystallization / Membranes Reverse Osmosis	✓✓	✓✓	✓✓	✓✓	✓✓	~	~	X
Water Spraying	✓✓	✓✓	X	X	X	X	X	X
Containment								
Physical Barriers Slurry Walls / Bio Barriers Sheet Piling	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	X	✓✓
Deep Well Injection	✓	✓	✓	✓	✓	✓	✓	✓

Symbols Explanation

✓✓	Maximum Applicability
✓	Moderate Applicability
~	Applicability Depending on Pollutant
X	Inapplicability

RIVER SHIELD 5D189

INTERREG III B CADSES