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Preface

Hydrocarbons spilled into the sea for whatever cause eventually strike a coastline somewhere, or at least that part that has not been removed from the water by some means of seaborne intervention.

The invasion of a coastline by oil slicks pushed by currents, wind and waves can directly impact the various kinds of coastal environments. For that reason the Ministerio de Medio Ambiente needs to be involved in the steps taken in response to events of this kind, in exercise of the powers vouchsafed it by the Coasts Act for the “protection, defence and conservation of the public marine and terrestrial domain and the use thereof”.

Precisely because of the great variety of littoral spaces and ecosystems, specific treatment is required, adapted to the characteristics and the environmental and functional needs of each one. These are elements of the region’s natural heritage which play a vital role in ensuring biodiversity and the exchange of mass and energy between marine and terrestrial environments.

The experience accumulated in this country through coastal responses to incidents of pollution caused by oil spills in recent years prompted the compilation of a number of intervention protocols by the Ministerio de Medio Ambiente. These have been successfully applied in the most recent incidents and constitute the embryo of this important publication by the Centro para la Prevención y Lucha contra la Contaminación Marítima y del Litoral (CEPRECO).

CEPRECO has now completed a more detailed and rigorous version of the existing action protocols and added new procedures which cover practically all possible situations and all possible types of coastal environment that oil slicks may encounter when they reach land.

This highly useful work by a recently-created body of the Spanish National Administration provides an effective response to one of the toughest challenges facing those who deal with the Spanish coast (especially in some highly sensitive and exposed zones), where they are called on to combat risks over which the country does not have complete control.

The appeal of this publication is universal, since it can be used as it is on any zone in the world and the procedures that it proposes are sufficiently tried and tested, based as they are on experience on the coasts of Spain and the efforts of thousands of people in tasks of cleaning and treating coastal areas affected by oil slicks washed in from the sea.

It is furthermore a pioneering documentary work in this field, where hitherto there was no publication that rigorously and systematically set down procedures on how to respond to coastal pollution by hydrocarbons.

And finally let me highlight a facet of the book that is especially appreciated by the Ministerio de Medio Ambiente –that is, the fact that it is oriented towards the preservation and restoration of environmental values and the biodiversity of littoral environments and ecosystems that are damaged or under threat during incidents of this kind.

For all those reasons, this publication constitutes a world benchmark on the subject, and therefore it is with immense satisfaction that the Dirección General de Costas, as the Ministerio de Medio Ambiente´s executive arm for preservation of the coast and coastal habitats, welcomes the appearance of what will surely come to be a classic in the literature on combating pollution.

José Fernández Pérez
Director General de Costas
Ministerio de Medio Ambiente

PREFACE

According to the Spanish Constitution, everyone has the right to enjoy an environment suitable for personal development, as well as the duty to preserve it.

Our geographical situation, the high incidence of the passage of oil tankers past our coasts and the bad weather conditions that prevail at certain times of year, all undoubtedly go to make this a very high-risk zone as regards maritime accidents. Indeed it is worth noting that Spain lies between two of the busiest shipping lanes around the European continent.

Consequently, we already have considerable experience of pollution from shipping accidents, which at the same time has contributed to a heightened social awareness of incidents of this kind. Governments and public authorities must adapt and perfect their organizational structures to meet the needs and provide responses, which have to be increasingly efficient to measure up to the demands of our citizens.

It is in this context that one must place the creation, on 12 November 2004, of the Centro para la Prevención y Lucha contra la Contaminación Marítima y del Litoral. Known by its Spanish acronym, CEPRECO, the centre was set up to assist in the protection and defence of our marine environment and coasts, but it was also a manifestation of the Government's resolve to lay down the foundations of permanent coordination and cooperation among the agents involved in these matters.

The vehicle chosen was an administrative structure reporting directly to the Vicepresidencia Primera del Gobierno, with an Executive Committee manned by representatives of all those executive centres of the Spanish National Administration having competences in combating marine and coastal pollution.

Among the chief competences vouchsafed to CEPRECO is that of promoting and directing studies on new systems for combating pollution and generally fostering scientific and technical research in this area. And hence, this book is intended to be the first of a collection of specialized publications that systematize and disseminate information and studies –in a word, the lessons learned and perfected in the wake of accidents like the Prestige spill– with the cooperation of scientific experts on the subject.

This first publication describes various practical procedures for the removal of oil residue from the coast, adapted to the natural and environmental conditions prevailing at a given site.

Some of the procedures described here are the fruit of the ongoing collaboration between the Dirección General de Costas of the Ministerio de Medio Ambiente and CEPRECO, while others have been compiled from scratch by the latter. All together, these chapters make up a comprehensive publication based on our own experience and predicated on the utmost respect for the ecological and geomorphological values presented by some parts of our coastline. In a word, we have systematized procedures that are necessary as tools with which to deal with hypothetical future cases.

At the same time, we also felt that this book ought to be published in English to favour wider circulation in the various different national and international forums in which CEPRECO has been involved practically since their inception.

This has been our commitment, and in CEPRECO we have been working to that end in the hope of being able to help and contribute to meeting the tremendous challenge of fighting pollution from oil spills and minimizing their effects.

Purificación Morandeira Carreira
Directora del Centro para la Prevención y Lucha contra la Contaminación Marítima y del Litoral (CEPRECO)
Ministerio de la Presidencia

Introduction

Coasts are fragile elements, formed in the course of millions of years by combinations of geological factors and shaped by marine and continental waters.

They constitute a transitional fringe between the sea and the dry land, a border that has seen changes in the course of geological time under the effects of plate tectonics and rises and falls in the sea level. Coasts are sites of an extraordinary explosion of life, promoted by the interchange between the two media and the mutual harnessing of possibilities. There we find successions of dune ecosystems, marshes, cliffs, etc., while in the subtidal zone some of the planet's richest ecosystems have developed; hence the obvious importance of protecting these spaces for the preservation of biodiversity.

The erosive action of the sea in turn produces singular developments of coastal morphology, creating formations of great scientific and scenic value which have come to form part of our common heritage.

A large proportion of the planet's population –and especially in Spain– inhabit the coasts, for the sea has always exerted a strong attraction on societies as a source of natural resources which they exploit by means of fishing, shellfish-gathering or marine farming, and also as a vehicle for trading and a medium of great potential for tourism and leisure.

These coastal margins are also sites of major production centres, taking advantage of rapid and economical access to a tremendous variety of raw materials, such as oil and its derivatives, which constitute a fundamental pillar of modern civilization and have found alternative transport routes in the sea.

INTRODUCTION

Seaborne carriage of oil generates a tremendous amount of traffic between production centres and refineries, and from the latter to sites of final consumption. According to 2003 facts, the total volume of this sector accounts for 35% of all international maritime transport.

But there is an obvious risk in seaborne hydrocarbon traffic produced by the uncertainty arising from the possibility of maritime accidents in general and of accidents involving vessels carrying hazardous goods in particular. Experience tells us that there is a convergence of various risk factors on certain coasts around the world: proximity of maritime traffic corridors with high incidence of hydrocarbon traffic; coasts subject to frequent strong gales; proximity of centres of production, processing and consumption; or old vessels plying in sub-standard safety conditions.

We have all witnessed scenes of desolation associated with large environmental disasters caused by spills from oil tankers, and such accidents are potent forces for social mobilization. Scenes of oil-covered beaches or marshes, oiled birds or fishermen who have suddenly lost their livelihoods, all produce major impacts and elicit an immediate flood of solidarity actions to palliate their effects.

Paralleling such major environmental disasters are numerous low-intensity pollution events produced by smaller spills but which present a high probability of repetition, as happens in certain parts of this country.

Efforts must be made to reduce controllable risk factors. Tougher maritime regulations which restrict navigation by sub-standard vessels, the introduction of numerous controls, regulation of maritime traffic and removal of that traffic from especially sensitive zones are all basic pillars of preventive policy.

By intensifying the above actions which constitute the basis of preventive policy, we can reduce the likelihood of a disaster, but even so experience tells us that there is always the danger of a chain of events that will cause a new spill, and in such an event it is essential to have access to procedural handbooks that will help managers to organize the response and cut down the time of uncertainty before decisions are taken.

In view of this situation and the evident vulnerability of our coasts, lying as they do close to some of the most important traffic corridors in the world, in November 2004 the Centro para la Prevención y Lucha contra la Contaminación Marítima y del Litoral (CEPRECO) was created to specialize in this field. The functions entrusted to it include facilitating coordination of the competent departments of the Spanish National Administration, devising instruments of cooperation with regional and local authorities, and promoting studies, protocols, contingency plans and generally anything that will serve to combine efforts in connection with the prevention and combating of marine and seaboard pollution.

In this context, CEPRECO is now working to unify and disseminate procedures for responding to spills and make them available to potential crisis managers. To that end we are working along with other government departments and specialized groups, making use of all possible experiences in various fields, which in most cases are highly dispersed.

The following pages describe eight action procedures for dealing with pollution caused by hydrocarbons in different spatial situations and time-frames. They take in everything from recommendations for the manual removal of oil to recuperation of oiled birds and innovative bioremediation techniques, including procedures for decontamination of beaches, rocks or special ecosystems.

These procedures were drawn up by the Spanish National Administration in response to the *Prestige* spill that happened in November 2002, which caused one of the worst ecological disasters in the recent history of Spain. Handbooks 2, 3, 4 and 5 were directed by technical staff from the Ministerio de Medio Ambiente at the time of the spill, with assistance from specialists in the various fields concerned.

In order to lend them more universal scope, this edition of the procedures, which were initially devised to deal with a situation of generalized pollution, have been supplemented on the basis of findings since then.

Handbooks 1, 6, 7 and 8 describe the latest experiences in this field of research nationally and internationally. They were directed by technical staff at CEPRECO with the assistance of specialists in various fields.

These handbooks set out the recommendations that should be followed by crisis managers to organize the response, both in the event of a low-intensity spill and if the disaster attains considerable proportions.

We will be glad to receive any suggestions for their improvement, to be included in future editions, for the fight against oil pollution is subject to constant change and is being rendered ever more effective. Every new event provides lessons which can be put to use in the future.

SCOPE OF APPLICATION AND METHODOLOGY

Handbook 1: Recommendations for manually cleaning of sandy beaches

This handbook lays down clear methodological guidelines for the organization of manual cleanup work in coastal sedimentary systems (sand/beaches) affected by an oil spill. It analyses the risks posed by such work and the appropriate preventive and corrective measures, and it makes recommendations for handling the waste that is gathered and conveying it to an authorized manager. It is intended as a guidance tool for managers and technical personnel who have to make decisions on the cleanup of an oil-polluted habitat of this kind.

One message that the procedure stresses is that organization of the cleanup work is as important as (or more important than) choosing the right method, and the same applies to safety measures, awareness of the risks and the implementation of adequate preventive measures (it details the rules on hazards, preventive measures and the personal protection equipment that workers must wear).

Once the managers or coordinators of the cleanup work on a stretch of coast have analysed the reports on the state of the sea then decided to work on a given zone and allocated human and material resources, the first step must be to properly demarcate the work area, including all the necessary infrastructure, and the second to instruct and organize the team members. The aim is to make the work more effective and efficient while minimizing the risks that this activity entails.

Handbook 2: Procedure for detection, analysis and diagnosis of fuel-oil in beach sand

This procedure addresses the need to assess the environmental situation of beaches that may be affected by an oil spill, which in turn requires an exploratory sampling of sediment to confirm the presence and severity of oil pollution, if any.

The procedure defines a sampling plan and provides recommendations on the sitting and optimum number of data-gathering points, and the number of samples that have

to be taken at each sampling point. It also details the analyses to be performed on each sample, the analytical procedures, what evaluation criteria can be established, and the human and material resources required to implement the procedure.

It is important to remember that the results and conclusions produced by these explorations are only valid for the time at which they are carried out. In the event of any substantial change in the type or the intensity of the pollution due to new oil deposits, the investigation will have to be conducted afresh, with new analyses and diagnoses.

Handbook 3: Procedure for cleanup of rocky areas and infraestructures by washing with pressurized water jets

This procedure is intended to provide guidelines for the cleanup of various types of coastal rocky habitat.

In most rocky coastal environments, the possibility of manual removal is limited by the viscosity and adherence of the oil impregnating the rocks, which can prevent effective cleaning by hand. Supplementary methods must therefore be found, particularly for the intertidal and supra-littoral zone, where waves and splashes have left oil stains, producing a major impact on the scenery and hindering environmental recovery.

This procedure considers two approaches to cleaning with pressurized water jets depending on whether or not there are living organisms on the rocks. The idea is to use seawater at ambient temperature where living organisms are detected and in sites of special ecological value, or hot water on rocks where there are no living creatures and on man-made structures such as promenades, dykes, breakwaters, wharves, piers, etc., or where the aesthetics of the area is an important consideration.

Whether the water is cool or hot, the pressure must be controlled to avoid dislodging or moving living organisms and contaminating the non-polluted part of the environment.

The handbook further describes and analyses the kinds of sites where this technique can be used, the working parameters, preparation of sites, conditions for application of pressurized water jets, progress of work on the ground, and the personnel and equipment required. It also deals with health and safety issues, particularly personal protection and decontamination of the people working with this technique.

Handbook 4: Procedure for cleanup operations of beaches with buried layers of oil

This applies to beaches where oil is detected in buried layers, provided that it can be removed with the relevant environmental precautions. The handbook describes the cleaning methods and the type of sites where they can best be applied.

INTRODUCTION

This procedure examines six general cases and proposes a methodology for each one, entailing mechanical means, manual means or a combination of the two. It also concisely defines the basic requirements for follow-up of this process. And finally it addresses the generation of waste and the pollution of clean material, plus the precautions necessary to prevent secondary pollution in sensitive zones.

Removal of pollutants must not cause worse damage than leaving them. For this method to be implemented correctly, the possibility of environmental impacts and secondary contamination from cleanup operations must be controlled.

Handbook 5: Procedure for cleanup operations on impacted shoreline vegetation and in areas of secondary pollution

Incidents of coastal pollution or cleanup operations themselves can affect certain sensitive zones, meaning those where the shoreline is associated with biological, social or geomorphologic/scenic values.

Any action on such zones requires a particular environmental diagnosis for each affected site and direct input from the technical specialists who were in charge of cleanup operations for the proposal of solutions. This procedure therefore envisages a preliminary phase consisting of an environmental analysis of the zone concerned, followed by definition of the target for cleanup, the characteristics of the waste, the operational methods and/or techniques, the environmental limitations and safeguards that should be imposed, an estimation of the resources required and the likely duration of operations; and finally an estimation of the additional actions needed for restoration of the affected environment, with a proposal for monitoring and follow-up.

This procedure also examines a number of cases of sensitive zones (populations of protected plant species, zones close to coastal peatlands, marshlands, etc.) affected by oil or by secondary contamination from cleanup operations, including recommendations on specific actions for each particular case.

Handbook 6: Procedures for cleaning of pebble and cobble beaches

Pebble beaches are a type of coastal geomorphologic formation that occurs at numerous places on the Atlantic coast; they are formed by marine deposits consisting of rounded pebbles or blocks which are considered to be points of geomorphologic interest. They are typically high-energy beaches and are known by many different names in Spain: “playas de cantos”, “playas de grava”, “playas de guijarros”; in Galicia they are called “coídos”, “cantís” or “boleiras”; in Asturias and Cantabria “pedreros”, and in the Canary Islands “playas de callaos”.

These formations are of considerable scientific and cultural value because of their geomorphology and their scenic beauty, and it is therefore essential to preserve the original structure of the beach in terms of its makeup and the arrangement of its component materials.

The procedure lays down methodological guidelines for urgent cleanup operations on pebble beaches in the event of an oil spill on the coast. These are intended to serve as a tool for managers and leaders of palliative operations when making decisions on cleaning up habitats of this type.

It also describes the various methods that can be used, such as direct mechanical collection, manual cleanup, softening in ponds followed by hydrocleaning, biostimulation with nutrients in ponds, and various ways of moving stones to the wave line. Finally, it cites other possible actions such as washing of stones at plant facilities, or flooding with water to clean zones in which pollutants have been washed up.

And lastly, the procedure also analyses the organization of operations and minimizing of environmental impacts produced by such cleanup techniques, and it provides specific recommendations for each type.

Handbook 7: Procedure for action using bioremediation techniques in rocky environments impregnated with fuel-oil

Bioremediation, or enhancement of natural petroleum biodegradation processes, is highly efficacious when mechanical means of pollutant removal cease to be effective. It consists basically in seeding affected areas with wild autochthonous or allochthonous petroleolytic bacteria or else adding auxiliary nutrients (N, P, Fe, etc.) and other bacterial growth activators, to promote the growth of autochthonous petroleolytic species.

According to a number of authors, since the middle of last century some five million tonnes of petroleum have been entering the sea yearly from a variety of sources. Long before now the situation would have been impossible to ignore had hydrocarbons been as non-biodegradable as, for example, some chlorate insecticides, or polychlorate biphenyls, terphenyls or naphthalenes. This shows that the biosphere metabolizes the various different components of crude oils.

This procedure is intended to establish guidelines so that the technique can be applied in oil-polluted rocky coastal environments; it provides some general considerations on its use, on the conditions of application on different types of shore and on its limitations and efficacy. It also defines the types of bioremedies, the appropriateness and efficacy of their application, the dosages and frequency of applications, and methods for assessing the effectiveness of treatments. Finally, it discusses bioenhancers (known microbial species which are able to assimilate hydrocarbons and present no biological risks) and analyses their varying degrees of effectiveness. The handbook has a series of annexes containing supplementary information about this technique.

Handbook 8: Recommendations for collecting and transporting oiled birds

There are protocols dealing with the treatment of oiled birds, but it is more difficult to find recommendations for their collection and transportation such as the ones contained in these procedures. The handbook provides basic recommendations to assist decision-making and identify some good practices for performance of the part of the work assigned to a wildfowl response unit when mobilized in the wake of a seaborne oil spill.

This procedure is intended both for persons in positions of responsibility in the management of the accident and persons who may be involved in an officially coordinated and recognized operation that is part of an organized general response. It should be noted that the procedure only deals specifically with seabirds, which as a rule are the ones most affected by a spill.

The handbook contains two clearly differentiated parts: the first is intended as a guide for decision-making in the definition of strategies to prevent oil affecting birds and their habitat; and the second deals with various aspects to do with the arrival of birds on the coast, from search strategies, techniques for the capture and handling of oiled specimens and first aid for live birds, to transfer to a rehabilitation centre for treatment.

Finally, it provides a number of practical recommendations for the release of birds following rehabilitation. It also furnishes practical information on issues of health and safety in the handling of wildfowl, along with data sheets on the principal seabird groups affected by such spills. This includes some essential information on their ecology and other practical recommendations for their handling.

HANDBOOK 1

Recommendations for manual cleaning of sandy beaches

1. OBJECTIVES AND GENERAL CONSIDERATIONS

This handbook seeks to provide guidance for managers and coordinators regarding future operations to clean up oiled sand, as well as methodological guidelines on organizing work, analysing attendant risks, implementing preventive and corrective measures and management, and the transportation to the waste treatment centre of waste from cleanup operations.

In its preparation, documentation from a variety of national and international sources (specialized centres, universities and environmental associations) was consulted. Also the recent experience gained during the management of the *Prestige* spill, with the various studies and protocols carried out by technical staff at the Ministerio de Medio Ambiente, has also been a basic source of training education. We trust that all this acquired experience and knowledge will be of help in achieving the earliest possible detection of potential problems caused by an oil spill so that the most effective cleanup solutions can be put into practice in each particular case.

Human chain removing oil waste from a beach.

2. ORGANIZING CLEANUP OPERATIONS

As important or even more important than the choice of cleanup method *"per se"* is the way cleanup operations are organized, since that assure greater efficiency in the outcomes and reduce the attendant risks.

Hence, once the managers or coordinators of the cleanup operation on a stretch of coast have analysed the reports on the state of the sea then decided to work on a given zone and allocated human and material resources, a coordinator is appointed. The coordinator will be responsible firstly for delimiting the work area, providing all the necessary infrastructure and then for informing and organising cleanup personnel.

2.1 Delimiting the working area

It is important to prepare the work area properly for removal of the oil and to avoid secondary contamination. Three areas must be marked out in each stretch of coast: a service or clean zone, an exclusion zone, subdivided into waste accumulation zone and personnel and equipment decontamination zone; and the area to be cleaned up.

2.1.1 Service zone

A base camp must be set up in an accessible area as near as possible to the working area. This will serve as a distribution zone for personal protection equipment and tools and as a general information point. This zone will be equipped with a changing room, toilet, canteen and store for the PPE and cleaning tools. The aim is to provide personnel with a comfortable waste-free area where they can change clothes, eat and rest.

2.1.2 Exclusion zone

Near the cleanup area there must be an exclusion zone for waste storage and personnel decontamination, thereby avoiding possible secondary pollution points.

1

This area will be divided into two clearly differentiated sections:

• **Waste accumulation section**
An accessible area must be properly delineated where waste is accumulated in bins or some other kind of totally sealed tanks. Before starting, the substrate must be protected with geotextiles and plastic-linem to prevent contamination from accidental spills.

• **Personnel and equipment decontamination section**
At each work site there must be set places for personnel and equipment decontamination. This measure will minimise possible episodes of secondary pollution. This area, properly marked off and covered in geotextiles and plastic-linen, must be provided with a container for equipment and one for contaminated PPE.
Depending on the type of operations, there may also be a specially adapted area for decontaminating machinery directly involved in oil removal.

2.1.3 Cleanup zone

It is advisable to cordon off the cleanup area prior to access by personnel. If possible, it should be staked out with highly visible markers so that each work group stays within a specific marked area for optimal organization and to prevent clean areas being polluted.
If there are sensitive or threatened areas, plant or animal species in the environs of the work zone, once they have been located, the area must be staked out, cleanup personnel must be properly informed and transit across the area forbidden (see Handbook No. 5).

1. Example of use of shovels to remove large oil stains.

2. Manual cleanup on an oil-stained beach.

3. Prepared decontamination zone.

2.2 Movement of personnel, machinery and waste in the working area

It is particularly important to mark off the most suitable routes for personnel and machinery to cross among the various parts of a work site. This will considerably reduce secondary pollution from cleanup operations.
The fact that personnel and machinery must always use these routes –known as "decontamination corridors"– must be stressed, as it is crucial in order to protect clean areas.
The decontamination corridors must always be in a sandy area that is completely free of waste, and marked with wooden stakes and special tape to prevent personnel and machinery from straying off the established routes.
Besides staking out the access zone, it is advisable to protect the track with plastic-linen or geotextiles that waterproof the ground to prevent personnel or machinery from unintentionally polluting the substrate.

2.3 Cleanup operations

Set out below are the steps to follow from the beginning to the end of a working day:
Firstly, all personnel must access the work site via the service zone, where they are equipped according to the kind of work they will be doing and properly informed of both the risks involved and the preventive measures that they must bear in mind. From there they transfer to the cleanup zone exclusively along the pre-established decontamination corridors, taking care not to walk over sensitive areas.
Once work is underway at the work site, waste removed during the various operations will be gathered in carriers. When a reasonable amount has been accumulated, it will be transferred to the accumulation zone along the pre-established decontamination corridor either by human chains or machinery.
At the end of the working day, personnel will proceed along the decontamination corridors to the decontamination zone, where they will leave their dirty clothing and tools in bins, and, fully decontaminated, move to the service area.

Figure 1: Work zone diagram.

3. WORK GROUPS. CHART

Appropriate training of personnel and careful organization are crucial in order to reduce the

risks associated with this kind of activity and to maximize work efficiency.
The coordinator of each zone is responsible for organizing the work groups and providing all necessary information.
The coordinator will appoint someone to be responsible for equipment and will divide operatives into groups of 10 to 20 persons depending on the size of the work site and the action points. Each group has a "Group Leader" and a "Clean Hands" person.
The person in charge of the equipment is responsible for providing protective equipment and tools for each kind of work. He or she will also inform operatives of the proper way to use the PPE, and at the end of the day must decontaminate and store equipment that may be used the following day.
The Group Leader will be responsible for defining and giving information about the kind of work that is to be done. He or she must also make sure that working regulations are complied with, organize waste removal to bins and monitor the equipment and needs of each work group.
The "Clean Hands" person is an essential feature in any chain of cleanup operations. He or she will be equipped with a full set of PPE but instead of work gloves will have latex gloves to make his or her job easier. He or she will help other operatives to dress and undress properly and attend to any queries from workers during cleanup operations (provide them with water, remove their mask for a moment, wipe their glasses, etc.).

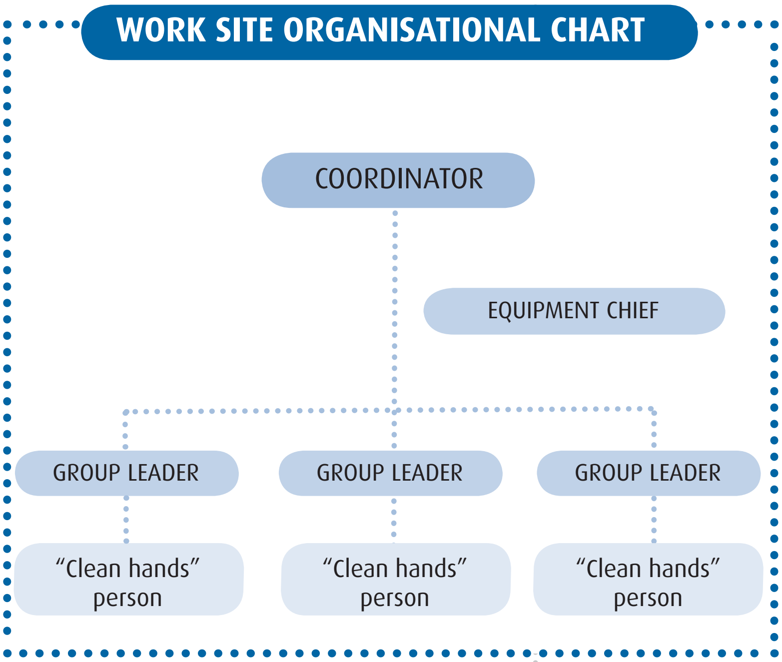
4. GENERAL RULES FOR CLEANUP OPERATIONS. CLEANING IMPLEMENTS

Manual cleaning of sand deposits must be performed in an orderly and coordinated way, and it is the responsibility of the coordinator and the group leaders to give appropriate instructions about the procedures to use.

- As a general rule stretches of sand should always be cleaned from the high water line seawards to avoide treading on polluted areas. A line of cleanup operatives should be formed parallel to the fuel interface and will advance towards the sea.

As much fuel as possible should be removed in the shortest possible time, ensuring that it is not dragged back by the tide or buried by moving sand. Therefore, larger patches should be cleaned first. In the case of one or several large patches not in the forefront of cleaning operations, a nearby area can be cleaned to make

Figure 2



a decontamination zone allowing personnel to access the most concentrated pollution area.

- The hydrocarbons should be left in drums or carriers fitted with handles or some other system that facilitates transport to the bin, where it will be tipped. If the distance to the bin is not very large, the operatives may transport the carriers by forming a human chain.
- On large beaches, as machinery will be used to transport waste to the bin, it is very important to mark off a corridor for the entry and exit of machinery. The corridor must be free of oil so that this is not buried.
- Coordination personnel should be in charge of providing tools and demonstrating their use.
- The basic tools for beach cleaning are trowels, shovels/spades and rakes. Each one is adequate for some kind of work, as it is important to remove as little sand as possible mixed in with the oil, thereby facilitating transport operations, storage and waste treatment, while limiting their effects and reducing the impact on the environment.

Shovels are suitable for removing large patches of oiled sand; garden rakes are good for removing cakes of oil on the tide line or floating in the water; other rakes are useful for gathering dry oil into small piles; and trowels are good for removing buried layers of oil and other tasks requiring more particular care.

5. RISK ANALYSIS AND PREVENTIVE MEASURES

Manually cleaning sand involves risk. People are working outdoors in unfamiliar surroundings and coming into contact with a dangerous substance. It is, therefore, crucial that work be carried out in an orderly and coordinated way. Workers must be properly trained and informed, and all potential risks associated with these activities must be analysed and provided for.

Given the risks involved, persons suffering from any of the following list should not be engaged in this kind of work:

- respiratory complaints.
- heart problems.
- liver patologies.
- skin patologies.
- pregnant women, children and elderly people will be prevented from taking part in these operations.

Where access is difficult, other means are needed –in this case a helicopter.

5.1 Rules regarding risks and preventive measures

Following analysis of the risks entailed in this kind of work, a number of safety rules and preventive measures have been devised, which should be compulsory (see Figure 4: SAFETY REGULATIONS IN THE WORKPLACE and Figure 5: SAFETY REGULATIONS FOR MANUAL BEACH CLEANING).

Substances and materials can find their way into the body in a variety of ways:

1º **Through inhalation.** Steam is breathed in and can easily pass through the lungs and into the bloodstream.

2º **Contact with the skin.** The pollutant reaches the bloodstream through the skin.

3º **Ingestion.** The pollutant is ingested by mouth through contact with polluted hands, drinks, food and cigarettes.

There is therefore a series of general rules or recommendations on personal hygiene:

- Avoid oil touching the skin at all times. Use the PPE provided.
- If skin accidentally comes into contact with oil, clean with a specific product to remove lacquers, resins, etc. NEVER use gasoline or solvents.
- Before drinking, eating or smoking, workers must wash thoroughly.
- Do not drink, eat or smoke in places where there is fuel.
- Non-disposable work clothing must be washed frequently.
- It is forbidden to drink alcohol in working hours as it may aggravate acute symptoms.

5.2 Personal protective equipment

The use of personal protective equipment (PPE) is compulsory for manually cleaning beaches and stretches of sand. It is not intended for any specific job but to protect from associated risks.

All PPE or its packaging must bear the "EC" logo and come with an information leaflet. The "EC" mark ensures that the equipment meets "basic safety and health requirements" for proper use. Together with the equipment, batch or packaging, an information leaflet will be provided explaining the different protection levels, duration, instructions for use, maintenance and, where applicable, the replacements needed. Within the European Union, PPE must meet certain requirements to guarantee user health and safety, called "basic safety and health requirements".

Figure 3

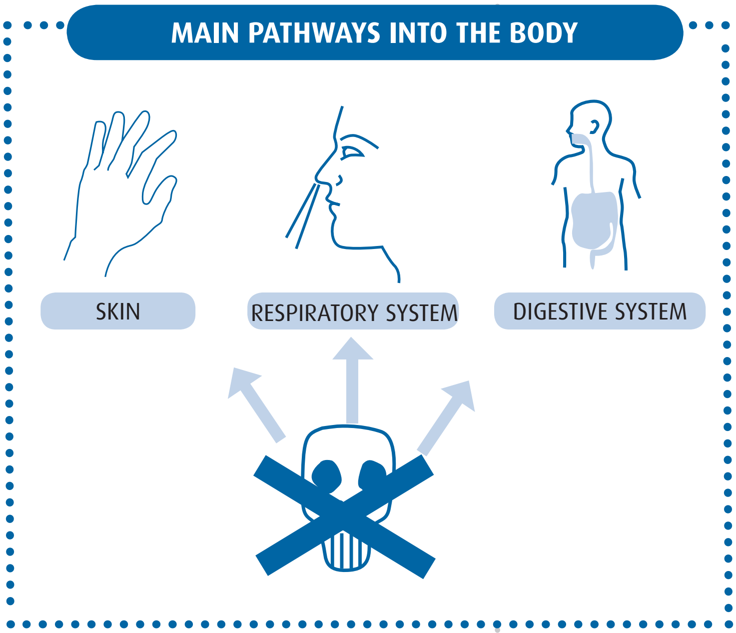


Figure 4:
Safety regulations in the workplace.

SAFETY REGULATIONS IN THE WORKPLACE

RISKS	PREVENTIVE MEASURES
• Falling on even ground.	• While moving around stay on safe ground; do not run downhill. • Keep your feet firmly on the ground while working. • Transit across specially fitted out zones. • Pay attention to where you are walking and be careful of obstacles.
• Being run over or struck by vehicles and machinery in transit and in work areas.	• Always be alert to heavy moving machinery in operation in the area. • Do not work close to or in the working radius of machinery and/ or vehicles in the aera.
• Falling into the sea from areas where access is difficult.	• Where there is a risk of falling into water, all operatives must always keep in sight of a workmate. • In areas that are difficult to access on land, account must be taken of tides and rising water level at high tide. If safety conditions are not satisfactory, work should be postponed.
• Falling while working on sites located on cliffs or boulder areas at a height of over two metres.	• Team leaders' indications must be followed at all times regarding the use of group and individual protection equipment depending on the case.

SAFETY REGULATIONS FOR MANUAL BEACH CLEANING

RISKS	PREVENTIVE MEASURES
Splashing when handling oil.	Be specially careful to avoid oil splashes. When handling fuel, use safety goggles.
Overexertion through keeping up incorrect posture when working.	Work at the correct height with a straight back, avoiding uncomfortable and forced postures. Keep up a constant work pace adapted to individual conditions. Do not try to pick up overly heavy weights. To lift a load, keep the back straight and bend the legs so that they take the strain when flexed. Work shall not take place in circumstances that noticeably weaken operatives' physical state. Use the right tool for each task.

Figure 5:
Safety regulations for manual beach cleaning.

1. Small oil "cakes" washed up on a beach.

2. Accumulation and transfer zone for oil polluted waste, staked out and protected with plastic-linen and geotextile.

PPE efficacy depends on proper use, and therefore operative training is essential.

Basic equipment:

- **Boots:** Must be waterproof, damp-proof and oil-proof. Boots prevent workers from getting dirty during the cleanup work or getting wet when working in damp areas. Boots must be cleaned daily.
- **Protective light suit:** Prevents workers from getting dirty during cleanup work. This equipment has a specific resistance to permeation and penetration by hydrocarbons. For manual cleaning of beaches and stretches of sand, Type EC Category III, Class 6-7 is recommended. It must be changed every day or whenever any kind of defect in the light suit is detected.
- **Mask:** Protects the respiratory system and prevents inhalation of volatile hydrocarbons. Masks must have a carbon filter and must be Type FFP2SL, which offers 10 times better protection at the limit value of exposure (10 x TLV). It must be changed once a day or when a smell of oil is noticeable through it or it has been accidentally oiled.

1. Detail of a decontamination zone for personnel allocated to oil-gathering tasks.

2. Manual cleanup of oil waste removed from a beach by two human chains.

1

2

- **Gloves:** Using the proper gloves will prevent skin from oil contact and penetration. They should be comfortable for working in. Long gloves made of nitrile or PVA are preferred. Neoprene or PVC are acceptable. They must always be changed if torn off or when they are so impregnated with oil that they are difficult to use.
- **Safety goggles:** Provide comprehensive protection against oil splashes and impacts from objects. Can be recycled and cleaned using suitable oils, but must be removed if cracked or impregnated with oil to such an extent that they are difficult to use.

Optional equipment:

- **Rain suit:** Protects workers in rain. Used under the protective overall to prevent it from being soiled and enable it to be reused. Must be changed when showing signs of wear.
- **Cap:** Provides sun protection when working outdoors.
- **Leggings:** Can be used over boots to prevent soiling; can be reused.

Gathering oil waste from a spill on a sandy beach.

PLEASE NOTE

- Use of personal protection is COMPULSORY.
- Unused or non-disposable equipment and clothing must be stored in such a way as to avoid contamination.
- Used disposable equipment must be stored in closed containers suitably marked as hazardous waste.

6. WASTE MANAGEMENT AND TRANSPORT TO THE ENVIRONMENTAL TREATMENT CENTRE

Proper management and transport of the waste removed from sand and other refuse that is generated by cleanup operations is vitally important. If the operation is not conducted properly, there may be secondary impacts on the environment.
As mentioned in section 2.1.2, a vehicle-accessible waste accumulation zone must be set up near the working area.
It is very important that special care be taken when separating waste resulting from beach cleanup operations, as the waste will be dealt with differently at the treatment centre.

Waste can be classified into:

- Fuel-oil and diesel (fuel or water-fuel mixes, gasoil used in cleaning tools or PPE).
- Earth and sand polluted with hydrocarbons (mixtures of sand and fuel).
- Protective clothing, plastics and wood polluted with hazardous substances.
- Containers with traces of hazardous substances (polluted carriers and disposable bins).

To separate waste, it is advisable to make metal bins available to store contaminated fuel and earth and sand, and plastic bins for clothing, plastics, wood and other packaging polluted with hazardous substances. It is advisable to line the bottom and sides of the oil containers with plastic to prevent leakage and make it easier to empty, as this also prevents fuel from sticking to the sides of the bin.


HAZARDOUS WASTE

HAZARDOUS WASTE

NAME:
Earth and sand contaminated with hydrocarbons

CER CODE: 17 05 03

952/97CODE: Q4//C15//S23//C51//H5//A102//B0005

OWNER:

Xn

HARMFUL

STORAGE START DATE:

COLLECTION DATE:

Figure 6: Example of hazardous waste labelling.

This waste may be taken directly in the bins from the accumulation zone to the treatment centre or may be centralized at a properly adapted transfer point for subsequent loading on trucks. If waste is passed at a transfer point from bins to dump trucks, it is crucial to keep the different kinds of waste separate.
Bins must be completely sealed and labelled according to the kind of waste they contain as provided by the current regulations on dangerous waste as laid down by the competent authority (see Figure 6).
Any moving of such hazardous waste must be done by hauliers authorized by the competent authority, and both bins and cradles must be properly covered.
To transport waste to an authorized control/ treatment unit, a number of administrative steps must be followed:

- Request acceptance document from manager.
- Give notice of transfer.
- Fill in monitoring and follow-up document (see Figure 7) and deliver waste to an authorized haulier.

HAZARDOUS WASTE CONTROL AND MONITORING FORM

HAZARDOUS WASTE: CONTROL AND MONITORING SHEET
(Article 36 - R.D. 833/88 - B.O.E. of 30/7/88 as amended by R.D. 952/97 B.O.E. of 5/7/97
and Order MAM/304/2002, B.O.E. No. 43 of 19/02)

Signature of person responsible for dispatch

Document no. **GA No.**

A. DETAILS TO BE COMPLETED BY REPRESENTATIVE

A.1. DETAILS OF PRODUCING FACILITY
Check box as appropriate: PRODUCER ☐ INTERMEDIATE MANAGER ☐

Company name	N.I.F.:
Name of facility	N.I.R.I:
Address	Province:
Town	Tel.:
Person in charge	Fax:

A.2. DETAILS OF WASTE TRANSFERRED

Acceptance no. Dispatch order no.
Relevant features for transport and handling

Code according to the European Waste List (EWL). Annex 2 Order MAM/304/2002
Description
Net Amount (kg)

Code according to tables in Annex 1 of R.D. 95/27

Table 1	Table 2	Table 3	Table 4	Table 5	Table 6	Table 7
Q	D		C	H	A	B
	R		C	H		

Description

A.3. DETAILS OF RECEIVING MANAGER

Company name Tel.: Fax:	Authorization no.
Name of facility	N.I.F.: N.I.R.I.:
Address Town	Province

A.4. COMPLETE DETAILS OF TRANSPORT PROPOSED

First transfer: Start date	Delivery date
Company name	Vehicle reg. no.
Type of transport	Tel.:
N.I.F. of carrier	Fax:
Second transfer: Start date	Delivery date
Company name	Vehicle reg. no.
Type of transport	Tel.:
N.I.F. of carrier	Fax:

B. DETAILS TO BE COMPLETED BY ADDRESSEE

Incidents in connection with details in block A:

ACCEPTANCE YES NO Signature of person responsible

Date

Signature (Full name): Mr/Ms

Source: Xunta de Galicia. Department of the Environment and Sustainable Development

Figure 7: Hazardous Waste Control and Monitoring Form.

HANDBOOK 2

Procedure for detection, analysis and diagnosis of the presence of fuel-oil in beach sand

1. INTRODUCTION

This handbook is a response to the need to assess the environmental state of beaches that may have been affected by an oil spill.
The first step proposed is an exploratory analysis of the beach sand in order to confirm the existence of some degree of oil pollution, if any. The verdict on water quality should be issued by the authority that normally runs these checks.
The following section defines the sampling plan designed for each target zone, the necessary analyses of each sample, the analytical procedures and the assessment criteria.
The results and conclusions produced by these explorations are only valid for the time at which they are carried out. In the event of any substantial change in the type or the intensity of the pollution due to new oil deposits, the investigation will have to be conducted afresh, with new analyses and diagnoses.

Fuel layer buried in beach sand.

2. SAMPLING PLAN

The purpose of the sampling design is to gather reliable information on the existence, concentration and distribution of hydrocarbons.
In its methodological handbooks for research into soil pollution, the IHOBE (Ingurumen Jarduketarako Sozietate Publikoa/Public Environmental Management Corporation), a public body engaged in environmental management, recommends three parameters for such definition:

- **Location of sampling points**
  On the basis of a potentially uniform pollution distribution in which it is initially impossible to

split the study area into small, well-differentiated compartments, the sampling points should be distributed across a staggered grid. Sampling must be simple and systematic, with triangular distribution of points to cover the whole target area. Figure 1 shows this type of distribution.
If clear evidence of significant spatial variation of the pollution is detected during the pre-sampling inspection, the location of the sampling points may be redefined, in which case a gradient type of systematic distribution should be used (see Figure 2).

- **Number of sampling points**

The number of sampling points should be proportional to the surface of the study area, preventing uneven distribution from affecting the overall evaluation of the detected pollution levels.
Bearing in mind that it is impossible to formulate an acceptable hypothesis for the pollutant distribution model, we recommend defining the maximum sampling intervals in X metres (longitudinal dimensions of the beach) and Y metres (transversal dimension of the beach) as shown in Figure 3, varying the number of sampling points in accordance with the size of the beach, as follows:

- **Beach length ≥ 1,000 m; 100 < X (m) < 150**
- **Beach length < 1,000 m;   X ≤ 100 m**
- **Y ≤ 50 m whatever the width of the beach, excluding dune areas.**

However, if fieldwork and "*in-situ*" inspection detects a particular zone that is severely affected by the oil spill, the minimum sampling frequency necessary to precisely define the pollution area should be defined using the IHOBE formula:
n= 10 +10A.
Where n is the number of sampling points, and "A" is the size of the target area in hectars (ha).

- **Number of samples**

At least a minimum number of one sample must be collected at each sampling point.

Figure 1
Systematic Triangular Distribution

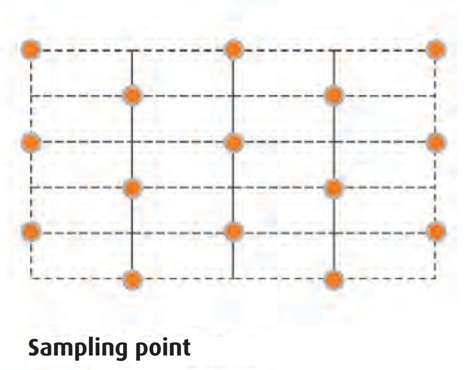
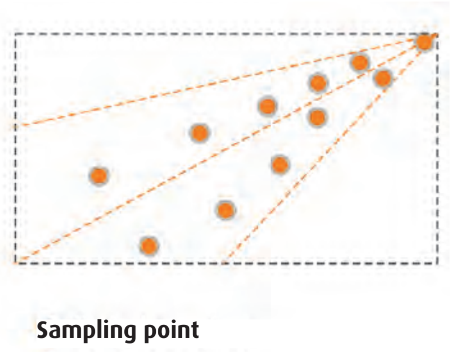


Figure 2
Systematic Gradient Distribution



3. SAMPLING METHODOLOGY

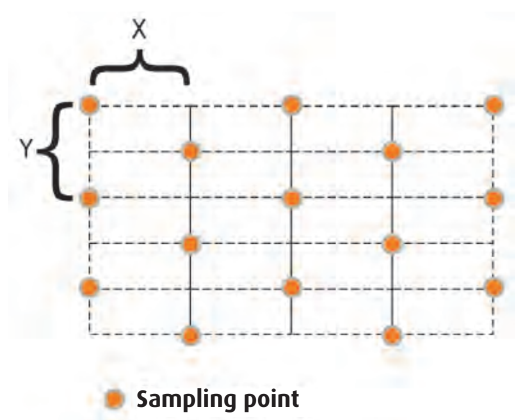
In order to identify possible oil slicks buried in the sand, depth samples should always be taken. This involves digging soil pits down to a maximum depth of 0.6 m. In each pit a sample is taken from the part where there is evidence of severe contamination or where the soil characteristics vary. In this way it can be gauged how deep any detected contamination goes.
It is important to note that surface sampling is not contemplated, due to the dynamic nature of the target sites (tidal variations, etc.) conditions, and surface and level conditions are constantly changing. A sample collected from the surface cannot therefore be considered representative of the real situation, given that the zone is periodically subject to systematic cleaning and will continue to be so until there ceases to be any appreciable new oil pollution.

4. POLLUTION ANALYSIS *"IN-SITU"*

To optimize the time spent on detection of the presence of fuel-oil, it is recommended to perform a quantitative analysis of potential pollutants (total petroleum-derived hydrocarbons or TPH) using *"in-situ"* analytical techniques which permit an accurate evaluation of the concentration and spread of the components on the beaches at the same time as the field work is being conducted.
For *"in-situ"* analyses, equipment for quantitative analysis of the total hydrocarbon content is required. Estimated analysis time per sample ranges between 15-20 minutes.
A hydrocarbon analyser is used to analyse the total TPH content at each sampling point (or soil pit). In this way a reference concentration is obtained for comparison with the reference criteria and thus allow to issue a preliminary opinion on the state of the site under investigation.

Pit sampling on a beach with buried oil.

Figure 3 **Sampling Point Locations**



HANDBOOK 2

5. POLLUTION ASSESSMENT CRITERIA

The assessment criteria described below were defined after comparison with unpolluted beaches and can be used to indicate that a beach is in a similar state as before the occurence of the oil spill, or if necessary to define some other kind of operation.
Where:

Np -peak measurement level of total hydrocarbon content detected by Petroflag in each sample (in ppm).
Nm -mean value of all measurements taken on each beach (ppm).

If:

- **1)**
  Np < 500
  Nm ≤ 300
  The beach is in a similar state as before the occurence of the oil spill.
- 2)
  300 < Nm < 5000
  The zone where the highest levels are detected must be analysed using lab tests and taking decisions by zones.
- 3)
  Nm > 5000
  An in-depth beach cleanup solution should be considered.

Detail of sub-sand oil level. Note the size.

6. EQUIPMENT

The following equipment must be provided:

- **Light equipment for on-site hydrocarbon measurements: hydrocarbon analysers, range of measurement: 0-10,000 ppm.** Most analysers of this kind are more sensitive to heavy hydrocarbons than to light hydrocarbons, but they allow the response factor to be selected according to the type of hydrocarbon that it is suspected may be in the sample (gasoline, diesel, fuel oil, hydraulic fluid, etc.). The analyser itself compensates the response factor for each analysis, correcting the final concentration in ppm. One decisive factor in the choice of chemical determination procedure is efficiency in sample extraction. It is

recommended that the system used contain no chlorinated or fluorinated solvents and that extraction efficiency not be affected by the presence of up to 15 % moisture in the analysed sample.
It is recommended that the analytical system used be approved by bodies which are competent in environmental matters.

- **Laboratory tests**
  A laboratory equiped with the necessary test equipment will be required to conduct all the analyses deemed necessary in order to cross-check the field results. This equipment must include a chromatograph for the analysis of samples evidencing a high level of pollution or presenting some uncertainty following *"in-situ"* analysis. Laboratory tests must define at least the TPH content, with chains between C_6 and C_{40}. Concentrations of polycyclic aromatic hydrocarbons (PAHs), simple aromatics, and metals may also be determined.

7. SCHEDULE

On the basis of the methodology described for sampling (soil pit) and for *"in-situ"* pollution analysis, each work team ought to collect a total of 20 samples per day, equivalent to a beach covering an area of roughly 2 hectars.
After completing the fieldwork, a provisional report on the results should be issued within 24 hours, and a final report on the analysed site should be completed within two days.
If laboratory tests are required, the deadline for submission of the report will depend on the number of analyses to be done, but under no circumstances should it exceed 7 days.

Example of analyser:
This should be an *"in-situ"* hydrocarbon analysis system covering a broad spectrum of hydrocarbon types up to a maximum concentration of 10,000 ppm. The analyser is basically a photometer –that is, an optical analyser that determines the turbidity of the solution prepared– and is very simple to use (calibration, sample preparation and measurement).

HANDBOOK 3

Procedure for cleanup of rocky areas and infrastructures by washing with pressurized water jets

1. BACKGROUND

1.1 General comments

On rocks, oil adheres to the surface, so that manual cleaning needs to be supplemented by specialized methods such as pressurized water jets, subject to a procedure that limits the impact of the cleanup operations.
As a preliminary measure, the contaminated rocky areas and infrastructures should be categorized into physiographic units in terms of morphology, soil conditions, ecological interest, physical environmental parameters and pollution characteristics in order to define priorities in the timing and extent of cleanup operation.

Detail of hyrdocleaning.

1.2 Environmental objectives to achieve during cleanup operations

The objectives are:

- To halt or not begin cleanup operations if the environmental impact caused by this work would be worse than the damage caused by not removing the oil.
- To temporarily suspend or defer cleanup work where the self-regenerative capacity of the environment is sufficient to achieve recuperation on its own. Periodic monitoring will be required to decide whether or not the cleanup work needs to be restarted.
- To forecast the secondary

environmental impact produced during cleanup work such as:
- Pollution of clean areas.
- Construction or alteration of conditions of access to the coast that could produce permanent environmental impacts.
- Destruction of natural environments through pollution or handling of sediments or vegetation.

1.3 Methodologies

The following recommendations depend upon location, impact and features of the oiled area:

- 1st In some parts of the coast, the most appropriate method for environmental protection is the "do nothing", for the following reasons:

  - The sea is an efficient cleaning agent.
  - To avoid negative environmental impacts from the construction of new accesses.
  - To avoid endangering participants in cleanup work.
  - To prevent secondary impacts and contamination .
  - Low toxicity of fuel-oil.

- 2nd In particularly sensitive areas, the possibility of periodic halts to operations should be considered as long as this does not entail permanent loss of ecological or socio-economic values.


1

- 3rd Action is recommended in areas where cleanup operations will allow faster regeneration of the ecosystem and where socio-economic values make this a priority.

Where action is required in such zones, the first and best option is manual collection until efficiency becomes minimal in proportion to the number of participants and resources utilized, at which point it will be necessary to carry on cleanup by other more suitable means in order to avoid permanent harm to ecological or socio-economic values, and to improve cleanup efficiency.

1.4 Cleanup schedule

In most rocky areas, manual removal of oil is limited by the viscosity and adhesiveness of hydrocarbons, which impregnate the rocks. Other complementary cleanup methods must therefore be found and concentrated in the area between the mid-tidal and the supratidal zones, where waves and splashing have left patches of fuel which delay environmental recovery and produce a major scenic impact.
For this reason, in the initial phase cleanup work should begin as soon as possible in areas whose importance for ecological considerations, shellfishing, fish-farming or tourism make time a crucial factor.
Cleanup work can then begin on other zones where specific, individualised studies are required.
Large areas where the timeframe is hard to predict will be left to natural cleanup and regeneration processes.


2


3

1. Hydrocleaning work.

2. Detail of water jet.

3. Hydrocleaning on granite.

2. CLEANUP PROCEDURES USING PRESSURISED WATER JETS

2.1 Operating principles

Cleanup operations must always be undertaken with the utmost sensitivity to the environment, which has already been harmed by pollution.
There are three methodologies regarding washing with pressurized water jets, depending on whether or not living organisms are present on the rocks, and on lithological structure.

- a) Seawater at ambient temperature on rocks where the presence of living organisms has been detected.
- b) Hot water on rocks with no living organisms, buildings, seafront promenades, dykes, breakwaters, wharves, piers, etc.; or where the aesthetics of the area is an important factor.
- c) In any of the above cases, water can be combined with sand on rocky edges with carbonated soils given its greater porosity, with the appropriate restrictions according to the type of rock.

2.2 Implementation zones

This procedure is intended for zones with highly stable substrates.
In rocky environments and zones containing infraestructure, this method is preferred in cases where cleanup cannot be left to natural recovery processes for any of a number of reasons:

- Rocks bordering and ornamenting beaches.
- Infrastructure, seafront promenades and beach access points.
- Pebble beaches or coves where cleanup is a priority for reasons of shellfishing, fishfarming or tourism (see Handbook No. 6).

Operative with appropriate PPE (mask, goggles, gloves, etc.).

2.3 Work parameters

The cleaning machinery that is used must meet the following specifications:

- 150 bars internal pressure, with 60/70 bars hose pressure.
- Average flow: 14 to 16 litres per minute.
- Must be capable of reaching a hot water temperature between 40° C and 50° C at the hose outlet.

2.4 Preparation of the working area

It is very important as a first step to prepare the work zone properly. For this purpose, the action proposal that is drawn up must cater for the particular physical and morphological characteristics. The purpose of this preliminary phase is:

- to protect the surrounding environment and avoid any spread of the pollution.
- to delimit the work zone and assure the safety of personnel.
- to position the necessary equipment to ensure optimum performance and avoid deterioration of materials subjected to the harsh conditions of the marine environment (salt water, sand, wind, etc.).
- to prepare for the containment and recovery of polluted liquid waste generated during cleanup operations.

Preparation of the work zone must be performed daily in all areas exposed to tidal action. It is a slow, repetitive task but is extremely important for the efficiency of the process.

2.5 Decontamination techniques

As noted earlier, the initial phase consists in preparing the zone to prevent the escape of cleanup effluent along with oil waste.

- The clean sand must be removed from the rocks before cleaning with pressurized water commences. In the event that an oil-impregnated rocky zone is covered with sand owing to changes in the beach profile, the oil-impregnated rock surface must be exposed before cleanup work can begin.

- At the base of all rocks or artificial constructions to be cleaned, a small collection barge should be installed wherever possible to facilitate decantation of the petroleum. A layer of geotextile should be place at the bottom. This is a flat, permeable, easily moulded material composed of thermoplastic polymeric fibres. The hydraulic functions of geotextile include filtering and drainage. Its mechanical functions include separation, reinforcement and protection.

Impact of oil slicks on a cliff zone.

- Geotextiles are also used to protect rocks and other clean substrates in the surrounding area from waste sprayed by the pressure of the cleanup equipment and the wind.
- Waste must be pumped to a tank.
- A barrier of absorbent polypropylene may be used to mark off the zone and prevent pollution spreading to the surrounding area.

Once the organization of the work area is complete and the recovery systems are set up, the actual cleanup work can begin.

2.6 Conditions of use of pressurized water

Pressurized water must be applied according to conditions on the rocky areas:

- **Zones without living organisms**
  Operators should always aim the jet of pressurized hot water from high points downwards and from the land towards the sea. Angles of incidence must be kept between 30º and 45º and not perpendicular to the rock.
  The jet must have a wide comb-nozzle and be applied from a distance of 10-15 cm from the surface to be cleaned. Closer ranges (5-8 cm) may be used where the oil is particularly thick. The jet should be moved methodically from top to bottom, from right to left and from back to front.
  When one cleanup sector is concluded, before starting the next one, a quick rinse should be performed from a distance of 30-50 cm from the rock to flush the material dislodged from the rocks towards the collection area.

Differences between hydrocleaned and oil-impregnated rock; absorbent sheets are used to protect clean zones and soak up effluent.

- **Zones containing living organisms**
  Water at ambient temperature should be applied perpendicular to the rock surface. An oblique jet can dislodge or crumble natural material and increase the mortality of organisms.

2.7 Operations in highly ecological sensitive areas

Even in an emergency such as an oil spill, it must be borne in mind that there are parts of the coast where there are special natural conditions,

and particular legal requirements regarding their protection and management.
In these areas natural environmental regeneration processes must take precedence over other more aggressive ones even if the latter may in principle appear to be quicker and initially more effective. Furthermore, it is important to avoid introducing substances alien to the local environment, particularly if they are long-lasting or are likely to produce a negative environmental impact.
Also, as the cleanup goes on, as much oil as possible must be removed from the natural environment and reduce the amount reaching the sea to a minimum, including what would reach the sea anyway through natural cleaning processes.
In these areas, hydro-cleaning with pressurized water jets at ambient temperature is recommended. To collect oil residue washed off the rocks, absorbent sheets and absorbent floating booms are used where the water runs into the sea.

- **Conditions of application**

  Where it is proposed to use this technique in rocky areas of high ecological value, the following recommendations should be strictly followed:
  - On rocky areas where there are cirripedes, limpets, winkles, mussels or similar dispersed intertidal species, it is important that these are not dislodged. A wide-spread, flat 25-degree fan nozzle is recommended, never to be applied from less than 30 cm from the rock. These application conditions are also valid for areas with live algae populations.
  - In supratidal areas with lichens, the flat 25-degree nozzle should be used, never closer than 30 cm from the rock.
  - As noted earlier, in rocky areas where there are living organisms, water should be applied perpendicular to the rock surface. Applying water at an oblique angle is to be avoided as it increases the chances of dislodging and killing organisms.

    In all cases as much of the dislodged oil as possible should be collected. To achieve this:

    a) Try to send cleaning fluids to a pool or area of standing water where absorbent sheets can be laid to catch the oil and removed as they soak it up. It may sometimes be advisable to use absorbent booms to contain the oil.

    b) Absorbent sheets should also be placed in all the cracks and channels where run-off collects, and changed periodically throughout the day.

Arrangement of hydrocleaning. Note safety measures and use of absorbent sheets.

c) An absorbent floating boom should be placed in the sea at the mouths of run-off channels. Absorbent sheets should also be placed within the retaining perimeter of the absorbent boom.

2.8 Progress of work *"in-situ"*

Before cleanup work begins in a specific area, work shifts must be organized based on the tide patterns. It is important to take advantage of times when work cannot continue on the rock faces to move people and equipment, and also to do any maintenance work that is required.
To begin pumping away residue from the cleanup area, pumping points must be chosen on the basis of the natural slope of the rock. They should be as close as possible to the spraying point. Where no natural collection points are available, small barriers should be built to contain the resulting mixture of oil and water.
Cleanup sprays should be directed in such a way that waste flows towards the collection or deposit points.
Waste must be collected while the rocks are being sprayed to prevent residue from building up at these points.
The teams must proceed in conjunction as the water level descends with the tide, coordinating movements to prevent oil from returning to the sea. Similarly, when the tide begins to rise, work and equipment must move back towards the high tide mark, leaving the recovery zones clean.
In distributing the teams, special care must be taken to prevent the recontamination of clean areas.

Arrangement of hydrocleaning materials.

2.9 Equipment

- Pressure cleaners, with hot water for some areas.
- Special filters for the use of salt water.
- Hoses.
- Pumps/generators.
- Tanks/deposits.
- Geotextile/absorbent barriers retainer barriers.
- Water bucket for washing.
- Fuel tank.
- Mobile crane for moving equipment.
- Sheds for storage, changing and toilets.
- Decontamination zone envisaged in this procedure.

2.10 Personnel required

A team of 10 people will be required for every 3 or 4 hydrocleaning machines. Personnel will also be needed for equipment maintenance.

2.11 Places where hydrocleaning is not appropriate

In some conditions this cleanup method is not advisable:

- When it is not possible to collect cleaning fluids (open sea and rough sea where it is not possible to place an effective containing boom).
- Where terrain does not permit safe working conditions.
- Where there are large numbers of vagile fauna (not sessile), e.g. amphipods, isopods, polychaetes, etc.
- There are large concentrations of sedentary fauna (limpets, winkles, etc.).
- There are large concentrations of algae and sessile fauna (sponges, anemones, bryozoa, etc).

In such cases where using pressurized water may wipe out communities of living organisms, it is advisable to consider other techniques that may allow them to survive.

3. HEALTH & SAFETY

3.1 Collective security

- **Objectives and principles**

The main potential risks in this work are usually falls by personnel and falling

Safety messures should be specially strict during hydrocleaning in cliff areas.

objects, primarily during raising, loading and unloading operations; burns; injury from blows, cuts or tying operations, hearing problems due to the presence of thermal motors; breathing aliments caused by dust generation and in all cases, hazards due to toxic pollutants.

- **Accident prevention**

The following rules are basic for accident prevention:

- Compilance with the legislation in force on risk prevention.
- Observance of organizational guidelines and works signposting.
- Individual protection must be guaranteed by equipping all participants with personal protection material (see "Individual protection") and taking all necessary steps to avoid risks. The latter should be identified in detail beforehand.
- Ensure proper personnel management to maintain the efficiency of teams and limit risks (shifts, rest times, coverage of physiological requirements on the ground, basic requirements, etc.).
- Establish a communication and rapid evacuation plan for cases of serious accidents.

- **Special attention must be paid to**

- Identification of personnel with basic health care qualifications and signposting of basic health care zones.
- Ban on smoking (and carrying cigarette lighters, matches, etc.).
- Remembering the tide pattern, particularly in places where access is difficult.
- In hazardous zones, team work is essential (no working alone).
- In all other zones, if individual action is required, contact must be maintained with the rest of the team (telephone, radio, etc.).
- In any event, if the necessary safety conditions cannot be guaranteed, the operation must be suspended until they can be satisfied.

An urban area before hydrocleaning.

3.2 Individual Protection

- **Personal Protection Equipment (PPE)**

For individual protection, appropriate work apparel should be used, consisting primarily of:

- Cotton underwear and clothes with the apropiate sort of natural fibres for the existing environmental conditions.
- Classic rainwear, type CE category I, usually known as “rain suit”. In some models, the weak points are seam strength and sealing. On average they last for five working days.
- Light protective suit, type CE category III, class 6-7. Normally worn on top of “rain suit”. For a single use on each work day or period.
- Non-slip boots with sole and toe protection, hydrocarbon proof.
- Long gloves, hydrocarbon proof. Inner cotton gloves are also recommended.
- When working with pressurized water, breathing protection masks type FFP2SL should be used, along with splash-resistant goggles. When hot water is used, it is recommend the use of visor-type masks for eye protection, as these cause less condensation problems.
- Skin protection with cream such as “Proderm” (CARAL) is recommended, or alternatively covering the exposed parts of the face with glycerine or Vaseline-based cream to facilitate cleaning in case of accidental contact.
- Helmets must be used wherever there is danger of falling objects or in the proximity of cliffs.
- It is also recommend sealing the wrist and ankle areas (where the suit meets boots and gloves) with adhesive tape or elastic material, taking care not to use excess pressure.
- It must be remembered to adapt clothing to temperature conditions and to drink fluids regularly to prevent dehydration.
- Decontamination is to be carried out at the end of each work session (see “Decontamination of personnel”).

- **Health protection for personnel**

  As with most hydrocarbons, heavy fuel-oil poses risks against which strict precaution and protection measures are required.
  It is an irritant for the skin and mucous membranes (especially the eyes).
  It contains compounds such as polycyclic aromatic hydrocarbons which in certain exposure conditions (very prolonged skin contact) pose a risk of cancer.
  In all cleanup operations, participants should therefore strictly observe the following health protection recommendations:

  - **Important remarks**

    Pregnant women may not take part in cleanup operations.

An urban area after hydrocleaning.

Persons with respiratory, heart, allergic, skin, lumbago or odour intolerance conditions may not take part in the cleanup operations.

- **General principle**
  Persons who are not physically fit must not be authorized to participate in cleanup operations. All participants in cleanup work must be informed about the precautions to take, equipped with appropriate material and be engaged by professionals, and a record of their personal details must be taken before they begin work.
- **Recommendations in case of accidental skin contact with fuel-oil**
  Do not use solvents (white spirit), gasoline or abrasive products.
  Remove as much oil as possible with absorbent paper (newspaper paper); dissolve oil with fatty products such as Vaseline or cooking oil, and then wash the skin with soapy water.
  In the event of serious accidental skin contact with oil, seek medical advice. The same applies in the event of symptoms such as headaches or digestive problems.

3.3 Decontamination of personnel

During cleanup of oil pollutants, workers' clothing rapidly becomes impregnated with hydrocarbons. Before leaving the work area, personnel must therefore be "decontaminated":

- To prevent the dispersal of pollutants over non-contaminated areas.
- To ensure at least a minimum level of comfort after each work session (meal breaks, etc.)

1. Arrangement of compressors and water tanks.

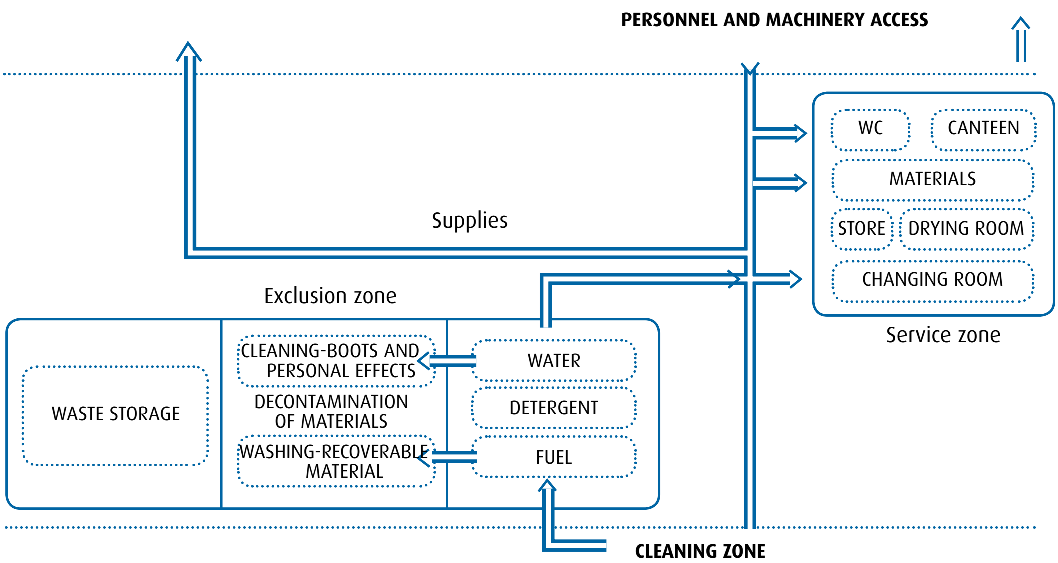
2. Another view of hydrocleaning using absorbent sheets.

- To maintain worker efficiency and prolong the life of equipment and materials as much as possible.
- Personnel must follow a washup routine from "dirty" to "clean", on a watertight platform where washing effluent can be recovered.

- **Base material**
  - A flat, slightly inclined platform (>30m²), plastic film to cover the platform and signs to mark off the decontamination area.
  - A 10-15 litre recipient with diesel oil or suitable cleaning product, plus rags, brushes, etc., to remove most of the product.
  - A second series of recipients, alternating rinsing water and detergents to remove traces of diesel.
  - Industrial rolls of absorbent paper for a final cleanup.
  - Two 200 litre tanks, with removable cover to collect solid waste.

The annexed facilities will consist of a work shed to store individual protection material, changing rooms, toilets and, where necessary, dining room.
All those entering the cleanup zone must observe the rules on personal protection equipment. All personnel leaving the work area must pass through the decontamination zone.
Effective personnel decontamination is achieved when it is carried out systematically for all the work equipment at the same time. Sporadic treatment should be avoided as much as possible.

ORGANIZATIONAL CHART



HANDBOOK 4

Procedure for cleanup of beaches with buried layers of oil

1. GENERAL COMMENTS

Sandy beaches are subject to cross-shore profile variability owing to changing hydrodynamic and eolic conditions which cause large movements of sand. Oil deposited on the surface of a beach becomes mixed with the sand, increasing its density, and may be absorbed into the beach's sedimentary system if not immediately removed.

2. ENVIRONMENTAL OBJECTIVES DURING CLEANUP PROCEDURES

This handbook establishes a cleanup procedure for beaches with buried layers of oil pollution so that it can be removed with appropriate environmental safeguards. It also defines basic mechanisms for monitoring this process.
Cleanup equipment and techniques must be adjusted to the established schedule and the environmental sensitivity of each environment and conform to criteria of efficient resource utilization.
Removal of pollutants must not cause more damage than if they were not removed. The possibility of generating environmental impacts and secondary pollution through cleanup operations must be monitored to ensure that this does not happen.

Manual removal of continuous oil layers.

3. CLEANUP PROCEDURES

3.1 Operational principles

As a general rule, action will be:

a) Priority on:

- Tourist beaches.
- Beaches where action can be taken most efficiently and quickly such as small affected zones, or where the absence of large-scale pollution is suspected.

b) Secondary in:

- Areas where the oil is buried at a considerable depth (more than 1 m), and people are unlikely to dig down to these layers in the summer months.

- Areas with very little tourism and pollution that is hard to treat.

Whatever the case, the cleanup methodology should be compatible with the following objectives:

- Prevention of seawater pollution.
- Prevention of pollution of clean sand.
- Prevention of waste generation due to inefficient excavator handling.
- Prevention of secondary pollution and environmental impact.
- Protection of most important natural habitats such as dune systems, lagoons, estuaries, marshes and in general any wetland close or adjacent to the beaches targeted for cleanup operations.
- Protection of geological, geomorphological and edaphological values, and of areas of special scenic value.

3.2 Implementation zones

Each operation zone has a number of characteristics that affect the choice of optimal cleanup methodology. For planning purposes, the factors that will affect operations must be considered:

Environmental features

- Machinery access.
- Aesthetic and/or scenic values associated with the singularity of the physical environment, or with its close relationship with nearby towns.
- Presence of plant and animal communities/populations of ecological importance.
- Presence of special geological, geomorphological or edaphological values, and of areas of special scenic value.
- Existence of officially protected natural areas in the immediate environs of the cleanup area.

1

- Bathing, fishing, shellfish gathering, etc.
- Characteristics of the beach (grain size, area, etc.)
- Other relevant information.

- **Characteristics of pollution**
  - Number of contaminated layers.
  - Average depth of the pollution.
  - Average width of contaminated layer(s).
  - Area of contaminated layers.
  - Location in relation to the tide:
    - Supratidal.
    - Mid-upper intertidal.
    - Lower intertidal-infratidal.
  - State of oil:
    - Fresh or weathered.
    - Continuous sheets/dispersed cakes.
    - Oil pellets.

3.3 Decontamination procedure

Two basic cleanup processes are defined: "non-active" and "active" cleanup:

- **Non-active cleanup**

Non-active cleanup is the generality of natural processes or processes of acceleration of natural degradation. This group includes bioremediation and natural attenuation, which although always supplementary to active cleanup, may be contemplated in isolation in certain circumstances.
This is a non-invasive process, although given the cleanup objectives and


2

1. Oil pellets in the lower intertidal zone which surface due to change in beach profiles.

2. Removing oil pellets at low tide.

intensive use of beaches on the spanish coast, it cannot be regarded as anything more than an ancillary cleanup process.

In these cases, the cleanup process is left to microorganisms, whose activity is artificially accelerated (see handbook 7), or alternatively they may be left to work without additives. The efficiency of these recovery procedures largely depends on the area of exposure, so that any process of elimination of fragments and thick layers can shorten the natural degradation process by several years.

The possibility of ploughing the ground to bring buried hydrocarbons to the surface may also be considered to facilitate manual collection of fragments or exposure them to light and an oxidizing atmosphere.

In any event these processes should only be undertaken in areas where one or more of the following conditions are given:

- Little-frequented beaches.
- Limited machinery access that is difficult to resolve without environmental damage.
- Activities linked directly or indirectly to the cleanup process are likely to cause a greater impact on the communities of interest (e.g. dune vegetation) than the impact caused by the pollution remaining in the sand (harm to communities of intertidal organisms).

These methodologies can only be applied if supplemented with periodic and strict monitoring of oil degradation to build up a documentary record of the experience and the conditions under which it takes place, while at the same time observing the progress of both the cleanup process and the regeneration of the natural values it is sought to preserve.

Digging trenches to locate discontinuous layers of oil.

- **Active cleanup**

There are two types of active cleanup:

- Cleanup by mechanical means (use of excavators, backhoes and sieves of varying mesh size). The use of others systems of particle separation by density and/or size should be assayed and evaluated.
- Manual cleanup with shovels and sieves.

A combination of manual and mechanical methods is also possible. Either of these two options is valid, although there should be some restrictions on their use.

The cleanup resources should be suited to the type of oil contamination present, although the chosen methodology may be modified in light of a need to speed up operations, detection of environmental sensitivity, etc.

Following are the general types of case and the methodology proposed for application in each one:

CASE No. 1
CLEANUP WITH HOT WATER

Characteristics of pollution
Cases where the sand mixed with fuel-oil is to be recovered:
- If the residue collected with mechanical sieves has too much sand and this fraction has to be recovered for the beach (separation is feasible with large-diameter sediment particles).
- When the sand is heavily mixed with fuel-oil in millimetre-sized particles, in one or more surface layers.

Substrate
Loose sand (this method should not be used in dune systems or estuary areas, and candidate areas should be inspected specifically before cleanup work starts).

Boundaries
The site should be roped off during operations
to keep out unauthorized personnel, channel transit and mark the progress of cleanup work.
Areas where work has already been done should be marked out.
The area where the waste matter is kept prior to treatment should be marked out, and the area set aside for cleaned materials should be planned to ensure proper distribution about the beach.
The area where cleaned material is dumped must be located in a tidal zone.

Preferential cleanup methodology
Excavators should be used to collect contaminated sediment and pour it directly into tanks with hot seawater, preferably salt-saturated.
The materials should then be stirred with a blower pump with manual power regulation. The oil can then be removed with hand tools as it rises to the surface.
Before the recovered sediment is dumped back in place, its state of cleanliness should be checked.
If oil particles are still present, the effectiveness of the process should be reassessed to decide whether or not it is worth continuing.

Environmental precautions
In all cases the necessary resources must be provided for the following purposes:
- To prevent water pollution.
- To prevent pollution of clean sand.


Manual screening of sand containing atomized waste.

• To prevent generation of waste matter caused by inefficient scoop handling.
• To prevent secondary contamination and impacts.

Remarks

This method should not be applied on a blanket basis, but only subject to approval by the managing organization. Preliminary tests must be conducted to ensure the system works in each case, since its viability depends on the sand grain size, its specific weight and the degree of inclusion in and adherence to oil particles.

Whenever there is any query about the application of the criteria described or any other alternative methodology is proposed, the presence of the monitoring team must be requested sufficiently well in advance.

CASE No. 2

CLEANUP OF MASSES OF OIL THAT APPEAR AT THE LOWER INTERTIDAL LIMIT

Characteristics of pollution

Oil that surfaces at the lower intertidal-infratidal limit due to changes in the beach profile.

Well-defined, compact masses of oil.

Substrate

Loose sand (this method should not be used in dune systems or estuary areas, and should be inspected specifically before cleanup work starts).

Manual removal of accumulated oil residue in the lower intertidal zone.

Boundaries

Once the patch of oil is located, no additional demarcation will be required if it is considered sufficiently large and accessible to be collected. The position of the detected mass should be marked where this is feasible.

Preferential cleanup methodology

• Mechanical cleanup: using excavators for direct collection of large patches of oil that rise to the surface.
• Manual cleanup: the mechanical operation can be supplemented with the use of manual shovels.

Environmental precautions

In all cases the necessary resources must be provided for the following purposes:

• To prevent water pollution.

- To prevent contamination of clean sand.
- To prevent generation of waste matter caused by inefficient scoop handling.
- To prevent secondary contamination and impacts.

Remarks

Programming of operations needs to be especially precise, since they must be executed within very limited hours and only for a short number of days each month (spring tides).

Whenever there is any query about the application of the criteria described or any other alternative methodology is proposed, the presence of the monitoring team must be requested sufficiently well in advance.

CASE No. 3

CONTINUOUS LAYERS OF FUEL-OIL

Characteristics of pollution

- Continuous layers of oil.
- Average thickness larger than1 cm.
- Existence of a layer of sand that can be removed from above the contaminated layer.

Substrate

Loose sand (this method should not be used in dune systems or estuary areas, and candidate areas should be inspected specifically before cleanup work starts).

Boundaries

Cleanup work may begin once the location of a layer with these characteristics is known.

Delimiting can proceed at the same time by digging soil pits under the supervision of the monitoring team from the managing organization.

The site should be roped off during operations to keep out unauthorized personnel, channel transit and mark the progress of cleanup work.

The areas where work has already been done should be clearly marked.

Preferential cleanup methodology

The following operations should be performed sequentially:

1. Mechanical removal of surface sand, preferably moving away from the sea.

Digging a deep pit with machinery.

2. Manual removal of the last layer of surface sand.
3. Manual removal of contaminated material.

Operations 2 and 3, if the conditions justified it, can be made by mechanical means provided that afterwards the residue is selected manually before being taken to the dump.

Environmental precautions

In all cases the necessary resources must be provided for the following purposes:

- To prevent water pollution.
- To prevent contamination of clean sand.
- To prevent generation of waste matter caused by inefficient scoop handling.
- To prevent secondary contamination and impacts.

Remarks

The possibility of mechanical removal of the surface sand should be determined in each case by the works supervisor on the beach.
The right average thickness for use of this technique should be estimated by the works supervisor on the beach.
Manual processes may be replaced by mechanical methods in areas where this expedites operations without any appreciable harm from excessive waste generation or unacceptable mingling of the oil layer with the clean sand.
Whenever there is any query about the application of the criteria described or any other alternative methodology is proposed, the presence of the monitoring team must be requested sufficiently well in advance.

CASE No. 4

OIL PELLETS RISING TO THE SURFACE

Removing a continuous layer of oil 1 cm thick.

Characteristics of pollution

Oil pellets rising to the surface

Substrate

Loose sand (this method should not be used in dune systems or estuary areas, and candidate areas should be inspected specifically before cleanup work starts).

Boundaries

Cleanup work may begin once the location of a layer with these characteristics is known, after informing the competent authority.
Boundaries should be defined visually using photographs taken of the whole area and details, which should be forwarded to the managing organization.

The site should be roped off during operations to keep out unauthorized personnel, channel transit and mark the progress of cleanup work.
The areas where work has already been done should be clearly marked.

Preferential cleanup methodology
The process should be performed sequentially:
1. Sweep up oil pellets with manual implements.
2. Manual sieving with <2-3 mm mesh.
3. A mechanical sieve with the appropriate mesh size may be used with dry sand.

Environmental precautions
In all cases the necessary resources must be provided for the following purposes:
- To prevent water pollution.
- To prevent contamination of clean sand.
- To prevent generation of waste matter caused by inefficient scoop handling.
- To prevent secondary contamination and impacts.

Remarks
Manual tools must be used under the supervision of a works supervisor to prevent unacceptable mixing of sand with oil.
Sieves should be the right size to optimize efficiency, and the material must be suitable so as to reduce fragmentation of oil to a minimum.
To improve the efficiency of the process, the possibility of drying the sand prior to sieving should be considered.
Whenever there is any query about the application of the criteria described or any other alternative methodology is proposed, the presence of the monitoring team must be requested sufficiently well in advance.
In mechanical sieving, the guidelines laid down in each case by the beach supervisor must be followed to prevent fragmentation of the crude oil and pollution of clean sand.

CASE No. 5
DIFFUSE LAYERS OF OIL

Characteristics of pollution
Polluted layers at a wide range of depths from surface but not forming continuous layers. Large number of continuous layers, too thin or diffuse to be removed manually or to be separated from the surrounding clean sand.

Substrate
Loose sand (this method should not be used in dune systems or estuary areas, and candidate areas should be inspected specifically before cleanup work starts).

Manual sieving.

Boundaries
Cleanup work may begin once the location of a layer with these characteristics is known, after informing the competent authority.
Boundaries must be defined by means of soil pits subject to authorization from the managing organization; the monitoring team must be present and photographs must be taken of the whole area and of details.
The site should be roped off during operations to keep out unauthorized personnel, channel transit and mark the progress of cleanup work.
The areas where work has already been done should be clearly marked.
Soil pits must be dug to assess the size of the polluted area.

Preferential cleanup methodology
Mechanical or mechanized sieving methods.
The ground may be ploughed to expose contaminated particles (provided that there is no other possible option).
During boundary marking and conduct of operations, some sites may be found where the procedure described in Case No. 2 is practicable.

Environmental precautions
In all cases the necessary resources must be provided for the following purposes:
- To prevent water pollution.
- To prevent contamination of clean sand.
- To prevent generation of waste matter caused by inefficient scoop handling.
- To prevent secondary pollution and impacts.

Delimitation of a work zone with deep contamination.

Remarks
In cases where the procedure described in Case No. 2 can be applied locally, the site should be properly roped off and the monitoring team informed.
Sieves should be the right size to optimize efficiency, and the material must be suitable so as to reduce fragmentation of oil to a minimum.
In mechanical sieving, the guidelines laid down in each case by the beach supervisor must be followed to prevent fragmentation of the crude oil and pollution of clean sand.
To improve the efficiency of the process, the possibility of drying the sand prior to sieving should be considered.

CASE No. 6
GENERAL

Characteristics of pollution
Any that match none of the above, or others for which a different approach is envisaged.

Substrate
Any type of substrate, and in any case the kind of coarse-grained sandy substrate that allows deep seepage of material, or else a non-sandy substrate. The viability of any methodology for dune systems or estuary areas should be examined before cleanup work commences.

Boundaries
In all cases the boundaries of the affected zone must be marked out as far as possible.
Areas where work has already been done should be clearly marked.

Preferential cleanup methodology
Alternative cleanup methodologies should be proposed and applied as available resources permit, for the following general purposes:

1. To prevent pollution of clean zones.
2. To prevent environmental impact.
3. To prevent generation of waste.
4. To fulfil cleanup goals.

The monitoring team must be furnished with enough information to enable the use of any applied procedure.

4. COORDINATION AND PROGRESS OF WORK

The following positions should be established in the cleanup team in each zone:
From among the personnel under him/her, the Coordinator of each zone should place a person in charge of buried layers cleanup for the beaches affected, whose functions will be:

- To check, review and ensure daily notification of the cleanup progress on the beach and the daily planning, in the format provided (see Annex I).
- To ensure that the cleanup work to be done is planned, that the managing organization is informed of this planning, and that there are adequate resources to carry it out.
- To check that the cleanup method used takes

Continuous oil layer in the upper intertidal zone.

into account existing environmental restrictions.

- To review and ensure the upkeep of a daily record of the resources used on each beach, and any incidents that occur during cleanup operations.
- To report periodically to the monitoring team on any aspect relating to these responsibilities, in whatever form they indicate.
- To review and collate new information on polluted zones not previously identified and report the evidence of such pollution to the Data Processing Centre.

  This responsibility should be assigned to a person with experience in oil cleanup work who also has environmental knowledge and training.

During operations a person should be placed in charge of each cleanup point, with the task of directing the work and ensuring that it is carried out in accordance with the precautions and methodologies established by the head of buried layer cleanup in each zone and the instructions of the managing organization.

This person shall also:

- Keep an up-to-date record of the characteristics of the pollution detected (as shown in Annex II) and the environmental characteristics of the affected site, and also ensure that all personnel involved in the cleanup work have an adequate understanding of them. This record must include photographic documents. All the information it contains should be clear, objective and reliable since it will be used to define the cleanup method and the resources required for it.
- Inform operatives of the overall and the daily target, and of the conditions in which the work is to be carried out.
- Keep a daily record of the resources used in each zone, the methodology applied and any incidents that occur during the cleanup operations. This record should include photographic documents.
- Draw up preliminary plans for the work to be done, which must be cleared by the head of buried layer cleanup in the zone. These plans should address the necessary resources and the overall and daily targets for the zone.
- The boundaries of the zone suspected of contamination must be staked out pending cleanup operations, unless special circumstances prevent this (e.g. daily flooding). Also, pollution-free zones must be signposted for the information of the public, and cleanup machinery and personnel should be kept out of them as far as possible.
- Furnish any information requested by the monitoring team from the managing organization.
- Follow the instructions of the managing organization.

In any event, personnel assigned to cleanup operations must be familiar with the characteristics of the pollution and the environmental values to be preserved, and they should seek information from their supervisors before beginning any new operations.

Continuous layer of fuel-oil in the upper intertidal zone.

The competent authority should provide an environmental monitoring team to supervise work, and whatever technical/environmental support may be necessary. This team will maintain contact with cleanup task supervisors in each zone. Before work starts they will define the environmental values that must be preserved intact, the authorized working methods and acceptable impacts during the cleanup process, and likewise the scope of the monitoring and environmental recovery work that will have to be done once the cleanup operations have concluded.
This team will collate the information from each visit, then it will validate the plans furnished by the various zones and the information on the work completed.

5. ENVIRONMENTAL ASPECTS

There are a number of environmental aspects relating to cleanup work that need to be taken into consideration. Following is a brief description of these, of the impacts that they produce, and of the means to minimize these when implementing any of the procedures.
The most important of these are:

- Generation of oil residue.
- Contamination from mixing with clean sand.
- Alteration or destruction of natural values due to impact on sensitive zones.

5.1 Generation of residue and contamination of clean material

The volume of mixed oil residue and sand that is generated will largely depend on the efficiency of the separation.
The environmental impact produced by the generation of such residue may be severe and should be reduced as much as possible by adequate segregation of the oil layer and the sand.
For this purpose, the following points must be considered:

- 1º. Use the appropriate machinery in each case to carefully separate the horizons of clean and soiled material.

- 2º. Inform personnel of the importance of segregating the soiled and unsoiled horizons to prevent the excessive generation of residue and contamination of the rest of the unaffected area. Ensure that all personnel involved in the cleanup work has been informed and are familiar with the waste segregation system (cleaning and disposal of suits, etc.), and the environmental values of each beach.

Self-propelled screening machine used to remove atomized surface pollution.

- 3º. Avoid ploughing/turning the ground for as long as the available time and resources are sufficient to permit prior removal of uncontaminated material.

- 4º. The extraction by mechanical means of clean material found on top of contaminated layers should be performed by at least two persons, one guiding work on the ground and the other handling the excavator, so as to ensure:
  - That the machinery does not pass over the layers of oil, preventing it from being cleanly removed.
  - That the machinery collects contaminated fractions from amongst the clean material.

- 5º. The extraction of contaminated material by mechanical means should be performed by at least two persons, one guiding work on the ground and the other handling the excavator, so as to ensure: that only the contaminated fraction is removed; that the machinery does not pass over the layers of oil, preventing it from being cleanly removed; that the contaminated material is deposited in the right container, always following the same route; and that spillage of contaminated material in transit is kept to a minimum and immediately collected by personnel.

- 6º. Waste dumps in the environs of the zone to be decontaminated should be sited in such a way as to obviate transit of contaminated material over the beach; if necessary, thought should be given to the transport method that produces least impact.

Towed screening machine cleaning a sandy beach.

- 7º. In cases where operations are being carried out in a sensitive zone in terms of fauna, flora, geology, geomorphology and edaphology, and/or of high scenic value, the monitoring team should run a check on the maintenance and/or recovery of biological values in the zone of operations. This team may also propose new procedures for monitoring natural attenuation, or operations for environmental recovery of disturbed values.

5.2 Secondary impact derived from intervention in a sensitive zone

Secondary impact derived from intervention on any environmentally sensitive aspects can in some cases be more serious than the actual presence of toxic materials.

Of the most important secondary impacts, particular care should be taken to avoid harm to natural elements of ecological or aesthetic/scenic value, and elements for public use.

- Disturbance of the physical environment (river banks, damage to rocks of ornamental value, etc.).
- Disturbance of vegetation or of geomorphological formations of significant value as being unique, representative, or having an ecological or scenic role.
- Disturbance of wetlands and hydromorphic soils in different stages of terrestrification.
- Disturbance of promenades, infrastructure, seafront access, private property, etc.

For this reason, the following points must be borne in mind:

- 1º. In any event, the possibility of access to the affected zone for the necessary personnel and machinery must be assessed, and a preliminary study must be conducted of the sensitive environmental elements and the expected characteristics of the pollution.

- 2º. Machinery and personnel in passage must always avoid disturbance to the environment around the access point; this must be planned beforehand subject to the supervisor's instructions.

- 3º. Personnel access to the site of pollution must be planned before cleanup operations commence, so as to avoid sensitive environments.

- 4º. The technique used must be compatible with the deadline set. At specific sites of high environmental sensitivity to the use of machinery, manual cleanup methods may be used if the resources needed to meet the deadline are available.

Manual removal of an oil pocket.

HANDBOOK 4

ANNEX I

Specific planning of buried layers cleanup and secondary contamination
(Including a fax sent daily to the monitoring team from the managing organization)

Beach name	Municipality	Zone no.	Beach code
....	....	....	....

Human resources	Internal Personnel		External Personnel	
	No.	Description	No.	Description
Mechanical resources and methodologies	Mechanical resources		Manual methodologies	
	No.	Description	No.	Description
WORK DESCRIPTION				
REPORTER				

1. Using self-propelled screening machines to remove atomized residue.

2. Using machinery to remove oil layers in the upper infratidal zone.

Annex II

Keep records and update if necessary; keep at the work area,
and send at the request of the monitoring team from the managing organization.

<table>
<tr><th colspan="2">Beach name</th><th colspan="4">Municipality</th><th colspan="2">Zone No</th><th colspan="2">Beach code</th></tr>
<tr><td colspan="2">..</td><td colspan="4">..</td><td colspan="2">..</td><td colspan="2">..</td></tr>
<tr><td>Sediment type:</td><td>Sand [ ]
Other [ ]</td><td>Presence</td><td colspan="3">State of oil[1]</td><td colspan="3">Size of layer [x]</td><td>Degree of certainty [x] of buried layers pollution</td></tr>
<tr><td colspan="2" rowspan="2">Contaminated horizons</td><td rowspan="2">(x)</td><td rowspan="2">1/2</td><td rowspan="2">A/B/C</td><td rowspan="2">Description</td><td>< 10 m^2 [ ]</td><td>< 10-100 m^2 [ ]</td><td>< 10-1.000 m^2 [ ]</td><td rowspan="2">Confirmed [ ]
Not confirmed [ ]</td></tr>
<tr><td>1.000 - 10.000 m^2</td><td>10.000 - 100.000 m^2</td><td>>100.000 m^2</td></tr>
<tr><td colspan="2">> 1m</td><td></td><td></td><td></td><td></td><td>Location depending on tide [x]</td><td>Supratidal [ ]</td><td>Intertidal [ ]</td><td>Infratidal [ ]</td></tr>
<tr><td colspan="2">1m - 75 cm</td><td></td><td></td><td></td><td></td><td colspan="3">Thickness of oil layer
1mm / 1 cm / 10 cm / 25 cm / 50 cm</td><td>Maximum [ ]Minimum [ ]</td></tr>
<tr><td colspan="2">75 cm - 50 cm</td><td></td><td></td><td></td><td></td><td colspan="3">Thickness of oil layer
10/ 20/ 30 / 40 / 50 / 60 / 70 / 80 / 90 / 100</td><td>Maximum [ ] Minimum [ ]</td></tr>
<tr><td colspan="2">50 cm - 75 cm</td><td></td><td></td><td></td><td></td><td colspan="4" rowspan="3">ACTION PROPOSED</td></tr>
<tr><td colspan="2">25 cm - 50 cm</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2"><25 cm</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">ENVIRONMENTAL SENSITIVITY TO BE AVOIDED</td><td></td><td></td><td></td><td colspan="5"></td></tr>
<tr><td colspan="2">REMARKS</td><td></td><td></td><td></td><td colspan="5"></td></tr>
</table>

1 State of oil.
- Fresh oil (1) or weathered oil (2)
- Continuous sheets (A) or scattered cakes (B) Oil pellets (C)

HANDBOOK 5

Procedure for cleanup operations on impacted shoreline vegetation and areas of secondary pollution

1. GENERAL CONSIDERATIONS

"Sensitive areas" are those along the coastline which possess biological and social or geomorphologic and scenic values which could be affected by the contamination or by cleanup operations.
To deal with such cases, a special environmental analysis is required for each oiled area, and input from environmental professionals .
It is essential that procedures be defined to establish the following:

- The present ecological and scenic situation, and the situation prior to the accident.
- Measures necessary to prevent effects of pollution on the natural / biological system that would become perceptible in the medium or long term, and requirements for monitoring of the recovery process.
- Information recording, training, coordination and environmental surveillance requirements during cleanup operations.
- Techniques selected for cleaning, transport and management of waste.
- Preventive measures required during operations.


Oil-impregnated marshy fringe.

This handbook provides guidelines for a cleanup procedure in areas with vegetation and/or environmentally sensitive areas which makes it possible to remove the oil with the necessary environmental safeguards to achieve the established objective.
It also defines the basic mechanisms for environmental surveillance of the cleanup process, the way in which complex actions should be proposed, the possibilities of complementary action, and monitoring requirements.

2. ENVIRONMENTAL GOALS AND PRIORITIES

The environmental consequences of the presence of contamination in closed and/or ecologically sensitive systems, and likewise the aesthetic effect on tourist or built-up areas, are regarded as more damaging than the possible secondary effects of cleanup when conducted in accordance with environmental friendly criteria.
The ongoing effect of the pollutants on the composition, size and nature of biological communities may cause an impact that would be hard to reverse. The essential basis for this observation is that in closed systems the period in which biological systems and weather conditions degrade the oil is by far longer than the time that the effects of pollution take to appear.
So the possibility of leaving the pollution in place is unacceptable except in areas where the following can be established:

- That the long-term effect of the cleanup operations as described in this document would clearly have more serious consequences for the biotic, physical or social environment than the presence of the pollution;
- That the impacted system is sufficiently open so that reversal of the impacts of pollution seems likely to be much more rapid than the emergence of these impacts to their full extent.

The scope of the action and complementary proposals for each zone must be established in line with the following objectives:

- To guarantee recuperation of ecological and aesthetic conditions and of availability of the oiled area for public use.
- To restrict cleanup techniques and establish auxiliary techniques to ensure that the operation will not have adverse consequences for the environment.

The action proposal must be backed up by an environmental analysis, so as to prioritize the environmental values that have to be protected, subject to an

1

assessment of the sensitive points of the zone.
The environmental asset that is protected in each impacted area must be made known to all those involved in planning, executing or monitoring the cleanup.
Systems must be organized in each area to ensure that participants in the operations and members of the public have a basic grasp of the aims of the operations. The following in particular must be specified:

- Objectives of operations.
- Restrictions that must be observed when applying cleanup and/or auxiliary procedures, to protect the environment.
- Requirements as regards public involvement in preventing secondary impacts until the affected areas have fully recovered, indicating what restrictions will have to be placed on use of the public maritime-terrestrial domain.
- Cleanup equipment and procedures must be adapted to:
  - 1. the environmental sensitivity of each setting;
  - 2. effectiveness in accomplishing objectives;
  - 3. general principles of efficiency in use of resources;
  - 4. the deadline established for accomplishing objectives.

3. ENVIRONMENTAL ANALYSIS

3.1 Information

The information required for action proposals is as follows:

- **Identification of impacted area**
  - Codification of affected area (alphanumeric code correlating to the coastline, allowing new keys to be introduced).
  - Unequivocal identification of the impacted zone (UTM coordinates, local name, code of nearest beaches, municipality, zone, map, sketch and orthophotograph).


2

1. Oil pollution of coastal meadowland on which plants have grown.

2. Decontaminating a dune system.

- **Environmental information**
  - Habitats existing within the area considered.
  - Official protection status of existing natural areas.
  - Sensitivity, singularity and representativeness of populations in the impacted area and animal and plant species.
  - Sensitivity of environment to access by transport/machinery.
  - Existing access.
  - Significant restrictions on action due to tides within the area considered.
  - Photographs of current situation (detail and general).
  - Thematic sketches.

- **Information on contamination**
  - State of the contaminant, depth, area affected.
  - State of plants.
  - Photographs of current situation.
  - Thematic sketches.

3.2 Documentation

The documentation must record data in a standard format to facilitate establishment of objectives, decision-making and proposal of measures. A suitable format has been devised (see Annex I), which can be digitally distributed to supervisors in each zone. The form, which can be sent by e-mail, should be supplemented with:

1. Digital photos (on CD, indicating source of digital files).
2. Communications via e-mail (corrections, incorporation of relevant new data, etc.) or by post.

Dune area adversely affected by oil collection operations before restoration.

3.3 Documentary analysis

The information furnished by technical experts in each zone should be cross-checked and completed with data from the monitoring and surveillance system.
The documentation that is obtained can be used to compile an Inventory of Sensitive Zones, Impacted Shoreline Vegetation and Areas of Secondary Oil Pollution, which will be the basic reference for the purpose of establishing objectives.

4. PROPOSING ACTION

Each action proposal should be made by the personnel responsible for each zone and assessed, completed, substituted or accepted by the responsble organization. The proposed action should refer to one or more areas of the Inventory of Sensitive Areas, Impacted Shoreline Vegetation and Areas of Secondary Oil Pollution.

- Establish cleanup target.
- Action methods/techniques.
- Environmental restrictions and preventive measures to be imposed.
- Estimation of resources required.
- Estimation of time required for cleanup operations.
- Estimation of characteristics of residue.
- Estimation of complementary operations required for restoration of the impacted area.

The action proposal should be based on a standard format, attached as Annex 2. The complete set of action proposals will comprise the document: Action Proposal for Sensitive Areas, Impacted Shoreline Vegetation and Areas Affected by Secondary Oil Pollution.

5. SURVEILLANCE AND MONITORING PROPOSAL

For each action proposal there should be a surveillance proposal drawn up by the persons in charge of cleanup surveillance, which will be evaluated, completed, approved or substituted by the responsible organization.
The surveillance proposal should deal with one or more areas of the Inventory of Sensitive Areas, Impacted Shoreline Vegetation and Areas of Secondary Contamination.
Surveillance and monitoring should be conducted while cleanup is in progress and afterwards; its aim will be to periodically check on proper compliance with the approved documents:

- This procedure.
- The Action Proposal for Sensitive Areas, Impacted Shoreline Vegetation and Areas of Secondary Contamination.
- Legal regulations regarding protection of nature and the maritime-terrestrial public domain.

Checks will also have to be made on the need to improve or modify the above mentioned documents in response to impacts not provided for or in the event that the measures or actions proposed prove ineffective (in terms of the established objectives).

Dune area adversely affected by oil collection operations after restoration.

After the action phase, the regenerative performance of the local environment should be checked with reference to the measures implemented, and studies should be conducted as necessary to determine the degree to which objectives have been met.

6. PERSONNEL TRAINING PROGRAMME AND ENVIRONMENTAL SAFEGUARDS

Training for all the staff involved in all aspects of oil removal is considered essential, particularly for persons who will be working in protected areas, in Special Bird Protection Zones (ZEPA), SCIs, Special Canary Island Zones (ZEC), RAMSAR wetlands or other areas that are valuable in terms of their ecology, wildlife or flora and which might be sensitive to the impact of cleanup operations (coastal lagoons, marshes, dune systems, estuaries, coastal peatland, etc.).
It is recommended that all personnel carrying out functions of any kind as part of the cleanup operation –beach surveillance, waste transport, cleanup squad or work unit leaders, and operatives– should receive some basic instructions regarding the fragility of the environment in which they will be working. They should also be made to understand the need to observe working procedures and the possible negative impact that failure to follow them will have on the environment.
It is important to stress that in many cases they will be working in areas where few people go, only frequented by wintering birds that arrive in autumn from Northern Europe. Such areas may sequentially suffer two kinds of disturbance:

- Impact from the presence of contaminants in the environment.
- Impact from the presence of cleanup personnel and infrastructures.

Impact of oil on shoreline vegetation.

It is therefore important that the personal profiles of the people engaged in this work be such as to assure a measure of environmental sensitivity and hence a stronger feeling of identification with the environment. The group leader of each work group should be capable of motivating the operatives in this way.
To that end a specific work plan should be drawn up for each of the natural settings mentioned (marshes, coastal peatlands, dunes, etc.).
The formation of work units (squads, crews, etc.) must obey a number of criteria:

- Number of people should be small.
- Personnel should be familiar with the kind of setting in which they will be working, and its environmental values.
- They should be familiar with the various preventive aspects addressed in the procedure (prevent transit through unauthorized zones, walk only along paths marked for that purpose, etc.).

Work should be carried out in a way that does not produce pollution or secondary impacts. Waste should, therefore, not be deposited in areas of sloping ground or in areas subjected to wave action or close to river channels or other surface waters. Parking areas should be defined away from dunes or flat sandy ground with vegetation, and strict discipline must be imposed as regards transit in the various working areas. The work, transport of materials and waste, movement of machinery and personnel, etc. must therefore be planned and monitored, and rules must be strictly complied with by all those involved in cleanup.
Partial impact on uncontaminated parts will only be countenanced where the scale or state of the pollution makes this unavoidable, in which case measures must be put in place to minimize damaging impacts.

Example of unstable dunes in a zone where cleanup operations have taken place.

7. OILING OR SECONDARY IMPACT DUE TO CLEANUP OPERATIONS

7.1 Impacted plant populations

Residue adhering to individual plants must be removed in the most practical possible way. In the selection of these, the following order of priorities must be observed as regards objectives:

- 1º To avoid contaminating unaffected plants.
- 2º To eliminate existing contamination.
- 3º To safeguard the possibility of achieving new generation (via seeds, breeding plants, etc.).
- 4º To preserve part of the impacted population.
- 5º To preserve the individual plant.

Aesthetic considerations must be assessed in each case in the light of public use; in any event the objectives pursued by such action must take into account aesthetic criteria and the convenience of green areas for public use.

7.1.1 Populations of sensitive plant species

Sensitive species are those which by reason of their special scientific interest, because they are endemic or officially protected or due to local circumstances (the local population may be important for preservation of the species regionally) merit special consideration and special efforts for preservation of the population.

In determining the actions to be taken and targets of restoration and conservation, population size and dispersal must be taken into account.

Marking of small protected species.

- a) **Small populations and/or populations comprising dispersed specimens**

In this case it may be very important to preserve every individual plant, as a possible focal point for propagation of the sensitive population.

Before cleanup starts, an estimate should be made of population density and distribution; also, requirements must be defined for surveillance and monitoring of the evolution of the population.

Simple, limited plans should be drawn up and implemented for collection of seeds (only in the case of the most sensitive species) for sowing later, cuttings or

some other kind of propagule depending on how the species reproduces.
The cleanup plan established for each zone under the supervision of the monitoring team should include procedures for making decisions on the cleaning of each individual plant, ensuring:

- That the environs of the action are signposted and there is visible protection for plants that must be left alone as being intact or recuperable, or as constituting a genetic reservoir to ensure a new generation.
- That plants which are irrecuperable and whose maintenance is therefore not viable are removed.

- b) **Large populations**

In this case it is chiefly the intact part of the population that should be protected; moreover, simple plans can be devised and implemented for collecting seeds, cuttings and other propagules (only of the most sensitive species) for later sowing.
Any cleanup plan must include procedures for making decisions on the removal of residue from each plant. Thus:

- Zones containing sensitive species should be signposted and passage through them discouraged.
- It may be enough to maintain unaffected parts of the population if in this way the affected ground is restored and cleaned in a manner more in keeping with biological processe.

7.1.2 Populations of non-sensitive plant species

For populations of affected plant species which are not classified as sensitive, efforts must focus essentially on removing pollution, stabilizing the terrain and restoring aesthetic values, but the vegetation should always be respected to the extent that decontamination allows.
In any case it is essential to signpost access routes, the zone of operations and uncontaminated areas, which should remain free of operations or transit.
Limited gathering of material to assure the genetic survival of affected plants may be allowable if there is some circumstance or ancillary operation that warrants it.

Restoration of a dune area affected by cleanup operations.

7.2 Special or sensitive contaminated zones

Sensitive contaminated zones requiring particular attention are those which present environmental features or factors that may be destabilized to some extent by operations in their vicinity. These zones are:

- Coastal wetlands.
- Coastal peatlands.
- Estuaries.
- Marshes.
- Dune systems.
- Eutrophic lakes.
- Fishing and shellfish zones, or zones important for these resources.
- Protected natural areas.

Special contaminated zones are those closely associated with human activities:

- Recreational/urbanized zones.
- Tourist and service zones.

As a general rule, environmental analysis, action proposals and execution must all be subject to strict surveillance by the control and monitoring team.
Where ecological values are thought to be under threat, monitoring should be proposed to conduct periodic checks on the progress of recuperation.

7.2.1 Presence of oil in river channels and estuaries

Zones occupied by running waters and more or less subject to tidal influence are sensitive zones. Pollution must be eliminated from riverbeds to ensure the recovery of their characteristic ecological and landscape functions.
Because of the diversity in size and importance of each contaminated zone, the solutions adopted require different degrees of planning.
The environmental experts in each zone should draw up an action proposal addressing the following issues:

- Scope of action.
- Description of the proposal.
- Any dredging required (volumes and surface areas).
- Any aggregate required (volumes and demarcation of areas).
- Ancillary equipment required (booms to contain pollution, etc.).

Contaminated wetland.

The objectives of the proposed action should be:

- Direct elimination of pollution from the affected environment.
- Prevention of contamination and secondary impact on the immediate surroundings.
- Preparation of the site for replanting and stabilizing of the physical environment.
- Maintenance of the affected habitat's ecological functions.
- Maintenance of existing resources (where there is fishing, shellfish gathering, etc.)

Depending on the scale of the proposal, and on-site checks on the extent of the contamination and the ecological state of the zone, it can be decided whether more detailed planning and study is required or whether work can start immediately subject to any modifications included in the proposal.

7.2.2 Presence of oil in areas close to coastal peatlands

There are a large number of coastal peatlands associated with wetlands, which can be mistaken for oil residue in the event of an oil spill.
It is therefore essential that cleanup personnel be aware of the scientific importance of peat and that any peatlands detected in the vicinity be monitored for possible secondary effects from the oil.
To that end, as prescribed in the Personnel Training Plan, operatives should be warned of the presence of peat and told how to distinguish it from oil. In addition, a cleanup protocol should be followed to ensure a high degree of selectivity and so prevent peat from being removed.

Boundary markers for a sensitive species, *Chamaesyce peplis.*

7.2.3 Contaminated vegetation along river banks or estuaries

Contaminated herbaceous vegetation along river banks should be cut above ground, taking care not to disturb the roots/soil complex.
In any event oil slicks in the direction of the river channel can be removed using

whatever manual means least breaks up the ground around the roots. In the event that the ground is completely impregnated, it should be considered whether to remove all the vegetation, including partial or total removal of the roots.
In such cases the channel must be stabilized using a combination of biodegradable elements (e.g. cocoa mesh, rolls of plant fibre, bales of native straw, etc.), plant sods from the same zone, seeds and topsoil of the same characteristics and origin as the soil removed.

7.2.4 Zones and structures for public use

This heading embraces areas used for recreational activities and containing elements or structures for public use, such as:

- Picnic areas adjacent to beaches.
- Play areas adjacent to beaches.
- Wooden walkways, paths in the vicinity of rivers, estuaries, dunes, etc.
- Gardens, parterres, etc. adjacent to beaches.

The vegetation in such areas has usually been artificially planted, and although its chief functions are aesthetic and to provide comfort in a seaside setting where people engage in leisure activities, in some cases it also stabilizes the physical environment.
This is an example of a zone where aesthetic considerations take precedence over maintenance of the ecological function of the plant cover. In any case the beach's stability must always be assured following the removal of contaminated vegetation.

Restoration of dunelands using sand traps.

The following objectives should be defined in zones of this kind:

- Identification and reporting of contaminated zones: soil, vegetation, infrastructures and urban equipment.
- Removal of soil, vegetation and other oil-contaminated waste.
- Identification and quantification of topsoil requirements to restore the plant cover in the area.
- Cleanup of contaminated infrastructures and equipment.
- Identification and cleaning (by simple means whenever possible) of damaged or contaminated equipment.
- Identification of zones of planted vegetation which serve to protect the physical environment (river banks, embankments, etc.)

Safeguards should be planned in such a way as to avoid the following during cleanup, gathering and transport of waste:

- Destabilization of embankments and river channels that are sensitive to the removal of vegetation.
- Secondary contamination.
- Damage, contamination or scrapping of structures that are retrievable or intact.
- Damage, contamination or elimination of vegetation (especially trees and shrubs which are important for purposes of aesthetics, substrate stabilization or convenience to the public).

7.2.5 Contaminated vegetation in marshy or boggy areas

In marshland with surface or subsurface pollution, very much subject to the rhythm and the effect of the tides, seasonal vegetation may grow on sediment that has accumulated on top of the contaminant.

If not removed, the oil may remain in the marshes for years, as they are protected from direct wave action and hence there is only very limited natural cleaning. Rapid and well-organized action will therefore be required on such an ecosystem.

It should be stressed the importance of training of personnel assigned to marshland cleanup operations, as they need to understand the fragility of these ecosystems and grasp the need to keep possible impacts on marshland flora and fauna to a minimum.

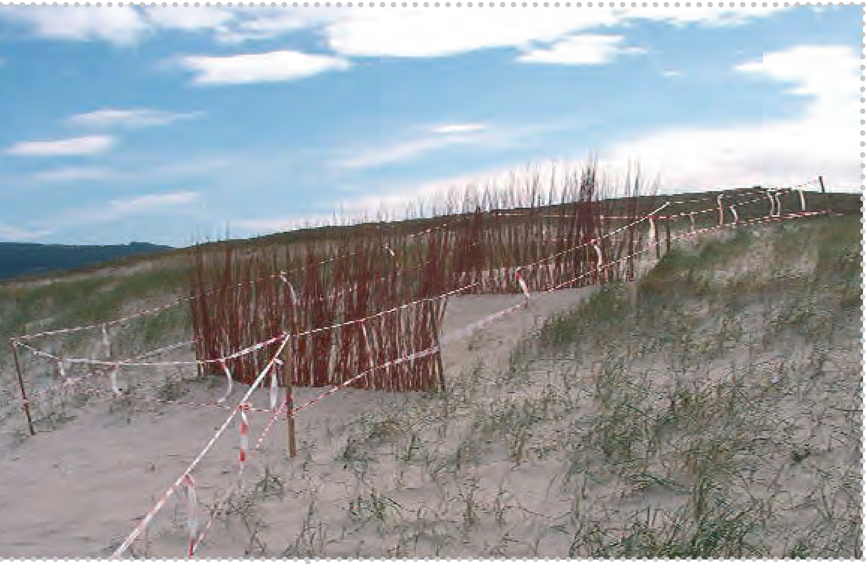
- 1º The aerial part of the vegetation must be removed in sectors where it is detected.
- 2º Following inspection of the terrain, planning must be drawn up for each zone:
  1) Defining the initial situation (species, populations, densities, etc.).
  2) Determining zones where the vegetation can be retained by removing surface oil.
  3) Determining zones where a large amount of sediment must be removed, along with the roots embedded in it.

Oil-impregnated vegetation on marshland.

4) Defining an action protocol for complete removal of fuel-oil and to ensure the possibility of ecological recuperation.
5) Drawing up a plan for the collection and upkeep of autochthonous sediments, seeds, cuttings and other propagules of the species found there.

3º Plans must be implemented in such a way as to ensure:

- That the oil is completely removed.
- That there is no appreciable change in the spot elevation of the area of operations.
- That maximum simplicity in waste extraction is combined with minimum impact on the environment, in particular avoiding loss of the latter's capacity for self-regeneration.
- That waste is not deposited close to river channels and surface waters or areas prone to flooding.
- That oil waste is not mixed with clean material, especially sediments that may contain the seeds of autochthonous plants.
- That zones in which vegetation is to be preserved are respected, by means of signposting and surveillance.
- That unnecessary use of transport machinery is avoided where this may significantly affect some of the sensitive elements identified.
- That no, or as few as possible, recipients, cleaning implements, machinery, etc. are kept in the working area.
- That steps are taken to avoid secondary contamination during cleanup operations, and that this is remedied if it occurs.
- That affected wildlife species observed during cleanup operations are identified. If need be, additional measures can be implemented for the recuperation of the species affected.
- That should it be decided to bring in materials for restoration and stabilization of the physical environment, they are of the same nature and origin as the existing ones.



Restoration of a temporary transit zone used during cleanup operations.

7.2.6 Pollution in dune systems

Dunes are such extremely fragile ecosystems. Mere passage through them can cause them to disintegrate. Regardless of the specific values of the species that comprise it in terms of special features, rarity or protection status, dune vegetation is an asset that needs to be preserved, as it is a structural element supporting the physical environment and the habitat that the latter sustains, besides being difficult and costly to restore. For all those reasons it is particularly important to keep strictly to a work protocol that must be understood and accepted by all cleanup personnel. This protocol should include the following items:

- Special emphasis must be placed on training the personnel assigned to work in dune systems. In particular, the importance of the flora in these systems should be explained to them.
- Transit of people, vehicles and machinery across the dunes must be prevented.
- Individual plants must be cleaned manually.
- The work area must be signposted to indicate clearly the limit and direction of clean up progress.
- Containers and dumps for oil must be placed both outside the dune system and its area of influence.
- Where a stretch of sand being cleaned extends along the length of the dune/beach ecosystem, the dunes must be roped off on their windward side, so that heavy machinery crossing the beach (only as strictly necessary) maintains the necessary distance to prevent affection of the heart of the dune.
- Only one access should be signposted.
- A limited number of persons should be assigned to the work, so as to ensure maximum efficiency with minimum secondary impact from movement of personnel about the dunes.
- Waste movement should be planned so as to minimize the number of journeys as far as possible to ensure that there is no secondary pollution. Passage of machinery over the dunes should be prohibited.

Protection of threatened species, *Rumex rupestris.*

- Waste collection points and dumps should be planned so as to occupy the smallest possible dunes area; under no circumstances should heavy containers be located on dunes.

a) **Zone occupied by completely contaminated plants**

In such zones, individual plants must be completely removed, along with any contaminated sediment. This should be done manually to avoid unnecessary or insufficiently selective removal of material.
During removal, a plan may be drawn up for the collection of seeds, propagules or specimens in good enough condition for use in restoring plant cover or seeding.
Previously, the population density must be estimated (if necessary on the basis of similar nearby zones) and the quality of the soil on which they stand must be gauged. Records of this should be kept, along with photographs, and used to scale and design any complementary restoration measures that may be necessary.
In cases where the removal of vegetation could lead to the partial or complete disintegration of the dune structure, the requisite retaining elements must be put in place to prevent it (material inputs, mesh, sand traps, etc.).
This can happen on dune slopes, on dunes in contact with estuaries or water courses and on dunes affected by the action of the sea.

b) **Partial pollution of individual plants over a relatively wide area**

Detail of contaminate dune vegetation.

Pollution may spread on the ground, over inert materials and plants.
In such zones, the complete removal of individual plants should be avoided as far as possible.
To achieve this, surface pollution must be eliminated by removing inert material with oil adhering to it and oil residue from the soil, without tearing away roots along with it.
The affected part of the plant must be cut away as efficiently as possible, proceeding in such a way as to ensure that the rest of the plant is viable and still fulfils its structural function in the habitat, and also constitutes a possible nucleus of propagation for the species.
Removal of the woody parts, or parts whose removal could cause the premature

loss of plants, should be avoided. If necessary in order to eliminate the pollution, at least the root system should be left if possible.

7.3 Pollution of rocky zones

It is referred here to polluted vegetation on cliffs or rock where the orography makes access difficult and specific decontamination techniques are required.
In such cases, besides the singularity, endemic nature or official protection status of the different species or communities found there, there is another factor that demands their preservation, and that is the structure of the physical environment.
In cases where partial or total removal of the vegetation is necessary, because of the difficult access, this should be done manually using appropriate cutting tools with handle lengths depending on the proximity of the affected trunks or stems.
Where vegetation cannot be accessed as described above, safety harnesses may be used, anchored to the cliff top or sloping rocks.
The use of rakes and other dragging tools that cause the loss of roots (which are usually alive, and often lignified) should be avoided, as they contribute to diminish erosion.

The following precautions should be taken when applying this technique:

- Whenever possible the action area should be roped off.
- A single signposted access point should be set up.

The direction of progress should be from the parts furthest away from the access to those nearest it, preferably in a downward direction. In this way the last task will be to decontaminate the access points and zones with most transit, thereby preventing secondary impacts in previously decontaminated areas.
A team should be assigned to ensure:

- Optimum control of safety during operations.
- Accomplishment of planned objectives.
- Maximum efficiency in use of resources.
- Minimal movement of personnel and equipment through the most sensitive areas.

Contaminated vegetation on a rocky fringe.

Waste removal should be planned so as to optimize efficiency and avoid:
- Risk situations for personnel.
- Indirect impacts on sensitive elements of the environment.
- Waste collection zones should be close and accessible, so as to avoid secondary impacts as a result of transit of machinery and/or personnel.

7.4 Vegetation and structures affected by secondary pollution from cleanup operations

Cleanup operations can damage certain zones. Many of these will regenerate spontaneously, while others will require complementary action to help their recovery, since they lose some of their most representative characteristics or else become unstable.

7.4.1 Unstable dunes

The unstable parts of dunes are usually on the dune front framing the dry beach.
Instability is generally caused by loss of material, often as a secondary consequence of impact on the vegetation. Possible options for restoration include the following:

- Placing passive wicker traps.
  Siting these in windy zones in combination (or not) with *Ammophila arenaria* or other suitable species will restore the volumes of sand that have become unstable.
- Adding sand
  Moving sand from the beach to the unstable zone will indirectly stabilize the bank, thereby:
  1. Halting dune erosion and destruction.
  2. Enabling nearby populations to recolonize the impacted area.

To supplement this action, it is worth considering planting, seeding and other techniques to speed up plant propagation.

Restoration of dunelands polluted by atomized residue.

7.4.2 Ruts made by machinery and vehicles and other impacted zones

Where there are zones with wheel ruts produced by machinery, restoration should proceed in three stages:

- **Restoration of sedimentary morphology**
  The zone where the substrate has been displaced should be filled in with material of the same kind and origin as in the surrounding area.
  Where the substrate has been compacted by compression exerted by wheels, it can be softened up first using hand tools.
  Restoration work should always start from the point furthest from the access point to avoid the need for transit during operations through parts that have already been restored.

- **Restricting access**
  Restrictions should be imposed in zones where the planning for this phase of the cleanup operations makes no provision for the roadways required for movement of personnel and machinery.
  In any case, in sensitive areas there must be physical impediments restricting the passage of machinery and vehicles. Also, specific signs should be erected announcing these restrictions.

- **Proposal for restocking with existing species**
  As an additional measure, in any zones where natural recovery is expected to be difficult, a simple restocking plan using propagules, plants, cuttings or seeding can be drawn up to promote initial colonization by plant species.

Restoration of dunelands deteriorated by cleanup operations, and removal of a temporary track.

ANNEX
Forms for identification and characterization of affected zones

Table No. 1

IDENTIFICATION OF ZONE[1]	
Beach code:	
Zone:	
Municipality:	
Reference book	
UTM X	
UTM Y	
Affected shoreline code	
Name of nearest beach	
Place name	

ENVIRONMENTAL INFORMATION ON THE ZONE[2]

Habitats in affected zone

[ ] Beach	[ ] Brackish wetlands
[ ] Dune front	[ ] Wetlands
[ ] Shifting dunes	[ ] River channel
[ ] Fixed dunes	[ ] Urban garden/Promenades/Parks
Notes :	

Official protection category

[ ] Natura 2000 network	[ ] ZEPA
[ ] Nature Park	[ ] National Park
[ ] RAMSAR	[ ] Local protection
Notes :	

[1] In principle to be completed by the biologist in charge of each affected Zone

[2] In principle to be completed by the biologist in charge of each affected Zone

Vegetation (species characteristic of the above habitats)

[ ] *Chamaesyce peplis*	[ ] *Juncus maritimus*
[ ] *Honkenya peploides*	[ ] *Typha latifolia*
[ ] *Elymus farctus*	[ ] *Phragmites australis*
[ ] *Ammophila arenaria*	[ ] *Rumex rupestris*
[ ] *Corema album*	[ ] *Omphalodes littoralis*
[ ] *Puccinela sp.*	[ ] *Salicornia sp.*
Other species (specify)	

Significant vertebrate species

Birds
Reptiles
Fish
Mammals
Amphibians
Other species (specify)

Means of transport and access

TYPE OF VEHICLE	ACCESS	SENSITIVITY
CAR		
TRUCK		
HELICOPTER		
BOAT		
OTHER (specify)		
TYPE OF ACCESS[4]		

[3] Should include those local species that may be most sensitive to cleanup operations and pollution; the sketch should indicate zones where this degree of sensitivity is likely.

[4] Indicate access characteristics with a view to removal of waste, possible restrictions due to sensitivity and absolute needs.

Table No. 2

Tide regime[5]

Characterization of state of pollutant[6]

[ ] Lumps (< 1 cm) [ ] Cakes (from 5 to 20 cm) [ ] Continuous sheet (> 50 cm)	[ ] Balls (from 1 to 5 cm) [ ] Sheet (from 20 to 50 cm)
Notes:	

Vertical characterization[7]

[ ] Deep contamination	[ ] Surface pollution
Notes:	

[5] Indicate possible effects of tides on cleanup work and sediment movements that tides may cause

[6] Indicate on sketch

[7] Indicate on sketch

State of pollutant[8]

[ ] Fresh	[ ] Weathered
[ ] Mixed with sediment	[ ] Not mixed with sediment
Notes:	

Affected area[9]

Affected area (m^2)	% pollution in zone:
Average % of affected area occupied by plants	
Notes:	

State of plants

[ ] Intact (apparently) [ ] Completely defoliated	[ ] Partially defoliated [ ] Dead
Notes:	

[8] Indicate on sketch

[9] Indicate on sketch

Table No. 3

REMARKS[10] :

[10] Additional information or relevant considerations should be entered systematically.

SKETCH[11] :

[11] If necessary for greater legibility, include a schematic sketch based on the same drawing.

Table No. 4

PHOTOGRAPHS[12] :

[12] Also add the 10-15 most significant photographs, a CD with photographs illustrating the affected area, applicable tools and methodologies.

AERIAL PHOTOGRAPHY (ORTHOPHOTO)[13] :

[13] Basic references to relate to the sketch should be marked on the photograph.

HANDBOOK 6

Procedures for the cleaning of pebble and cobble beaches

1. GOALS AND GENERAL CONSIDERATIONS

The purpose of this procedure is to establish a set of urgent-action methodological guidelines for the cleaning of pebble beaches (also called “coídos”, “boleiras”, “pedreros”, “kantal-hondartza”, “playas de callaos”, “platges de códols”, etc. in different geographical regions in Spain) in preparation for a future hypothetical oil spill along the coastline.

It is first of all important to distinguish between the concept of cleaning and that of decontamination of an area affected by a spill. The actions referred to in this chapter do not focus on decontamination. The goal here is to achieve an acceptable degree of cleanup by removing the greatest possible amount of oil in order to promote and accelerate the subsequent natural restoration of the affected area.

In the aftermath of an oil spill, there are many varied factors which come into play in terms of the pollution and subsequent cleaning of a stretch of coastline. Probably the main variable is the type of pollutant spilled, which will have a bearing on its possible negative effects on the different coastal habitats and on the impact that cleaning work will have.

Another variable is the type of habitat affected, because the impact of the spill and subsequent cleanup efforts will vary depending on the type of coastal ecosystem affected.

The selection of a cleaning method for pebble and cobble beaches is a complex decision, and there are a large number of variables to be considered which will be vital to the conservation of these unique natural areas.

Example of an active area.

This handbook is intended to help in the taking of these decisions by seeking to integrate all possible variables and sharing experiences and recommendations acquired in different campaigns, to supplement the voluminous existing documentation regarding the cleanup of coastal oil spills.

Chapter two highlights the geomorphologic and environmental value of these coastal systems and the possible effects that a spill may have on them.

Chapter three describes the different methods which have been used, to a greater or lesser degree, to clean pebble beaches in the case of recent spills affecting the Spanish coastline.

It should not be forgotten that each worksite has its own set of characteristics which make it unique, thus demanding a specific strategy which is not always valid for other similar areas. With a view to facilitating selection of the best cleaning method for each cobble beach and minimizing the impact that cleaning efforts have on the environment, chapter four and subsequent sections focus on an action protocol and work recommendations.

In drafting this procedure an examination was conducted of existing documentation from different international organizations such as CEDRE (Centre de Documentation, de Recherche et d'Expérimentations sur les Pollutions Accidentelles des Eaux), NOAA (National Oceanic and Atmospheric Administration – U.S. Department of Commerce), EPA (U.S. Environmental Protection Agency), Alaska Department of Environmental Conservation – Division of Spill Prevention and Response, ITOPF (International Tanker Owners Pollution Federation Limited) and IPIECA (International Petroleum Industry Environmental Conservation Association), among others.

This handbook also reflects the experience gained following the *Prestige* spill, which is documented in numerous specific work reports and protocols of the Spanish Ministry of the Environment, reports and studies conducted by the Consejo Superior

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de Investigaciones Científicas (National Science Research Council – Spanish acronym CSIC) and different Spanish university departments, and likewise reports drawn up by various NGOs.

2. PEBBLE AND COBBLE BEACHES

2.1 Geomorphologic and environmental value

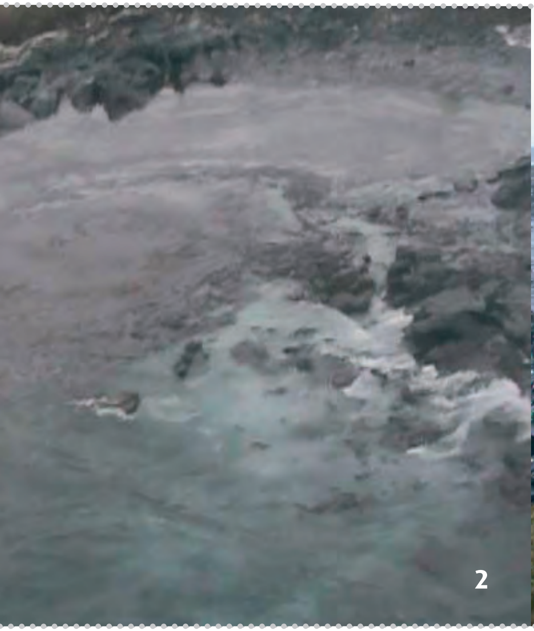
Pebble beaches are a typical geomorphologic coastal formation found along many areas of the coast.

These marine deposits, formed by the accumulation of smooth stones or weathered blocks, are characteristic of high-energy beaches and are considered to be of geomorphologic interest.

Such stones are known by a number of different names (“cantos”, “grava”, “guijarros”) which all loosely translate as pebble. Names also vary from region to region and in Galicia these stones are known as “coídos”, “cantís” or “boleiras”, in Asturias and Cantabria the term “pedreros” is used, in the Basque Country “kantal-hondartza”, in the Canary Islands “playas de callaos”, and in Catalonia “platges de còdols” or “codolars litorals”.

These rock formations may be steeply sloped with a series of berms forming on the upper part of the beach, due to wave action. The degree of exposure to wave action may vary considerably from one beach to the next and a distinction can thus be drawn between active areas (high rate of wave energy) and inactive areas (low rate of wave energy).

In active areas where there is very high wave energy hitting the rocks, the result is an accumulation of rounded stones of homogeneous size and shape,



1. Example of an inactive area.

2. Areas of rocky edge with large quantities of fuel oil.

3. General view of oil puddles covering cobbles.

all within a certain size range. This is characteristic of areas subject to unstable ambient and oceanic conditions (waves, storms, etc.) and therefore the situation is variable with interspersed periods of calm seas.
Inactive areas where the wave energy level is much lower, for example pebble beaches or parts of them situated beyond the reach of the breakers, are much older beaches, formed approximately 120,000 years ago when they were more open to the direct weathering effect of the sea and waves. The materials composing these beaches are of heterogeneous size and shape, are more difficult to classify and are characterized by their angular shapes. Conditions on these types of beaches are subject to less change, although they too can be affected by strong storms which only exceptionally move the larger stones. This environmental stability favours the flourishing of biological communities of the high meso-littoral zone (area only inundated at spring tide) and also in the supra-littoral zones where numerous lichens and plants grow. This is where the habitats in Annex I of the Habitat Directive (Natural Habitat of Community Interest) can be found, along with the vegetation associated with these geomorphologic formations.
While the density of plants and animals on open pebble beaches in the intertidal zone is typically scant, it can be high in the case of inactive beaches and in the lower intertidal zone on all beaches. Many feature populations of unique plant species which are threatened or even in danger of extinction (*Rumex rupestris*, *Chamaesyce peplis*, *Omphalodes littoralis*, etc.). Others may be found in the vicinity of nesting areas of endangered bird species (*Charadrius alexandrinus*). This is, in short, one of Europe's best preserved Atlantic coastal systems.
And lastly, the importance of preserving these pebble beaches must be stressed and impressed upon cleanup teams. They have important scientific and cultural value given their geomorphology and natural beauty, and it is therefore essential to preserve their original structure in terms of the order of materials and the general configuration.


Manually cleaning of a cobble beach.

2.2 The effects of a spill

Cobble beaches present a number of characteristics which favour the build-up and persistence of oil. Their high porosity enables the freshly spilled oil to rapidly seep down relatively deep and penetrate the finer sandy sediments, thus complicating cleanup efforts tremendously. While the surface layers of these beaches look clean,

oil may persist in the underlying sediment for a long time.
On the rocky shelf, cobble beaches and coastal cliffs, the lower part which is exposed to the action of the waves will be free of oil but the upper part, which is less exposed, is more likely to be splattered with pollutant matter.
Natural cleaning of the surface layers of cobble beaches is limited by the abrasive capacity and energy of the waves to remove these deposits. Thus, in areas where the size of the cobbles is smaller and/or these deposits are mixed with sand, the friction can aid in the elimination of oil stains. Moreover, given that this type of beach typically has an irregular profile, the residue may not last long in open areas exposed to the action of the waves, but in other areas where the wave energy is much lower (inactive zones), or where fuel oil has seeped down to the finer sediment layers, it could be there to stay for quite some time.
In the active zones of these beaches where wave action is particularly strong, it can be assumed that once fuel oil deposits have been removed, sea energy will be sufficient to complete the cleanup naturally.

3. ALTERNATIVE CLEANING METHODS

In this section we describe different methods which may be used to remove fuel oil from pebble beaches. It includes proposals requiring different degrees of intervention and varying time frames.
Given the large variety of environments presenting these characteristics (different geomorphology and accessibility, different conditions of marine dynamics and landscape value), a particular cleanup method should be selected only after careful consideration of all the factors.

Oil on the beach substrate.

3.1 Action of the sea and its energy

On rocky cliffs with little sediment build-up which are very exposed to wave action, it may be advisable not to undertake any type of cleanup action at all. These areas, featuring a high rate of natural recovery, have a narrow, steep intertidal zone with slopes in excess of 30º, making the use of machinery and the placement of containers for residue removal impossible and the access of cleanup personnel extremely dangerous.
At this kind of site the best option may be to take no action, in the hope that the action of the sea will be sufficient to achieve partial decontamination. During the first several months following the arrival of the oil, these areas typically remain impregnated, especially in the high intertidal and supratidal zones. However, after a few more months, given the high rate of natural cleanup characterizing cliff areas, most of the fuel oil is washed away thanks to the strong wave action. Following the winter months, certain supratidal parts may still retains some remains of the heaviest fractions of the residue which the sea and time will break down.

3.2 Direct mechanical collection

Mechanical machine-aided collection is a method which can be used in areas where large quantities and thick layers of oil have collected. This method may be very useful in rocky areas with an elevation of only a few metres above sea level making access of cleanup personnel and machinery relatively simple.

1. State of a beach with large quantities of oil.

2. Volunteers cleaning up oil on a pebble beach.

3.2.1 Use of skimmers

This is an alternative method for the collection of fuel oil deposits in sheltered areas. It can be used when the viscosity of the oil is appropriate for the proper operation of this equipment, suiting the latter to spill characteristics as market availability permits.
This would not be an ideal option in the case of high-viscosity oil or emulsified or old material.

3.2.2 Use of earth-moving machinery

In certain circumstances viscous oil can be removed with machinery and then deposited in containers or dump trucks.
The scoops of these machines collect the fuel oil directly and deposit it in containers used as intermediate holding tanks. From there it is loaded on to properly sealed dump trucks and taken directly to hazardous waste treatment plants. Once the amount of residue is reduced to a level where mechanization is no longer practical, these areas can be cleaned manually to achieve an acceptable degree of cleanup. At this stage, attention must be given to areas where plants are affected, cleanup of buried layers, hydrocleaning, actions to accelerate natural processes by moving cobbles down to the surf zone, biostimulation through the application of oleophilic nutrients and, if necessary, eliminating access paths opened for cleanup machinery by replanting.

3. Human chain removing oil in baskets

4. Another example of a human chain removing oil in baskets.

3.3 Manual cleaning

This is the method most frequently used for the cleaning of pebble beaches affected by oil spills. It is the most effective system for the removal of fuel oil from cobble beaches and one of the methods with the lowest environmental impact, but it requires a large number of personnel (see Handbook No. 1).

Generally speaking, most of these works can be undertaken on pebble beaches where there is adequate access. Some cobble beaches with difficult or dangerous access can also be cleaned manually by teams of specialists or groups who are familiar with the affected coastline, such as shellfish harvesters or fishermen.

The fuel oil is collected manually using trowels, spatulas and other scraping tools in order to remove the greatest volume of residue possible from the surface of the cobbles and from the puddles forming around them. The fuel oil that is removed is collected in baskets or plastic bags, which are subsequently emptied into skips or big-bags situated in the vicinity of the work area.

In many cases it will be necessary to set up human chains to transport the baskets or bags full of fuel oil to the place where the skips or big-bags are located. On steeply-sloping stony beaches, a pulley or cable system can be set up to lift the baskets and plastic bags to the containers above.

Once this first-stage urgent cleanup has been conducted, the next step is

1. Manual cleaning on a pebble beach.

2. View of cleanup work on a pebble beach.

to remove the fuel oil from beaches where it has settled under the rocks (deep contamination, percolated fuel oil). This second stage of cleanup is carried out using metal crowbar-type leverage tools, and in some areas with the assistance of light machinery (mini-backhoes, light duty tracked vehicles, etc.).

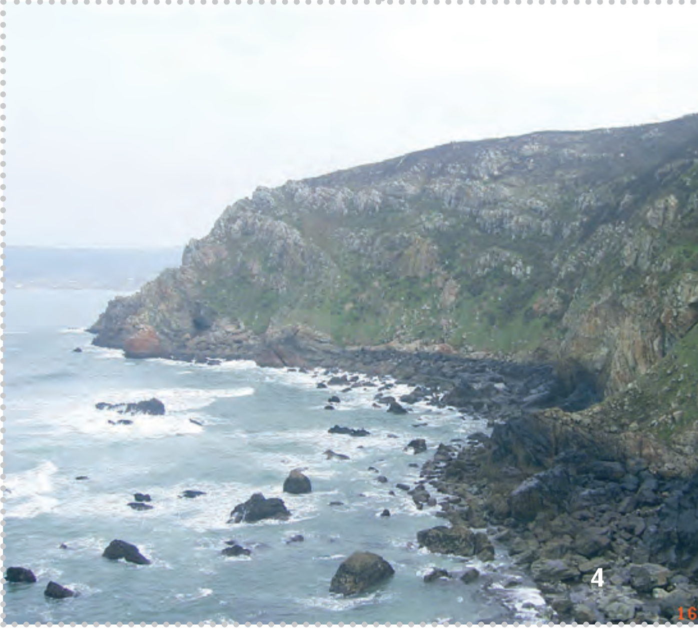
In other cases, after first checking with experts in geomorphology, machinery can be used to move the heavier rocks and cobbles, thus facilitating the manual work undertaken by cleanup personnel.

At these sites, the transport of the skips and big-bags with the residue is very important. The methods and machinery used in this connection will vary depending on the access conditions at each of the work areas. Where possible, skip-carrier trucks will pick up the skips where they have been set up and haul them out. In areas where land access is difficult, the use of helicopters may be necessary to carry the oil to the waste transfer zones.

In some cases where there are large amounts of oil, for better and faster removal of the residue, the opening of provisional access roads may be considered to facilitate the movement of machinery for transport of the containers.

Corrective measures should be envisaged to remedy the environmental impact resulting from the clearing of these access roads. Once the heaviest work has been concluded, restoration work should begin by removing access roads and restoring the original profiles, slopes and geomorphology, and replanting as needed.

3. Helicopter carrying containers from a beach.



4. General view of a rocky edge with difficult access.

3.4 Making a pool for oil softening and subsequent hydrocleaning

The area should be first cleaned manually to remove as much oil as possible, so that the residue remaining on the beach is reduced to a thin film covering the surface of the cobbles.
This technique entails submerging contaminated cobbles in sea water to hydrate and soften the oil and make it easier to remove using hydro cleaning techniques.
Structures can then be built to contain water in pools, taking advantage of the natural slope of the terrain and the rocks and cobbles themselves, so that they merge as well as possible into the surroundings. This prevents erosion of the sandy substrate, as it is never exposed to wave action.
As in previous cases, this work should be supervised by specialists.

Pool construction can be summarized in the following steps (see series of photos):

- Study of location in terraces in the supra-littoral strip and setting out taking advantage of natural structures.
- Removal of pebbles either manually or with the help of light machinery, taking care not to damage the sandy substrate on which they rest.
- Construction of the walls of the pool resting on the rocks and using the cobbles themselves.
- Waterproofing with a layer of semi-rigid 1.5 mm thick polyethylene which is then covered with a black plastic liner over which a third layer of 120 g/m^2 geotextile is added.
- The pool is then filled with the oil-impregnated material using the backhoe and then manually spreading the stones to level the surface.

Right-hand page
Preparing a pool for softening and subsequent hydro cleaning of cobbles.

1. Initial state of the affected area.
2. Building the pool walls using cobbles.
3. Fitting the plastic liner.
4. Once the pool is ready the stones are placed in it and it is filled with water.
5. Hydrocleaning of softened cobbles.
6. Replacing clean cobbles.

Example of beach with fuel seepage on to the substrate.

Manually cleaning a beach with the help of machinery.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- Sea water is then pumped in until the cobbles are completely submerged. For large stones in some areas, pools with a capacity of approximately 5 m^3 can be used.
  The hydrocleaning process can begin after several months. This work is performed directly on the pools, so that the structures can be dismantled as the cobbles are cleaned. Where the cobbles are submerged in metal containers, hydrocleaning is done by placing them on metal grids.

The residual water in the bottom of the pools and containers (with a high fuel content) should be pumped into a tank and taken to the appropriate authorized waste management centre. Lastly, the geotextiles and plastic liners are removed and the cobbles are returned to their original location (either manually or with the aid of a backhoe) trying to restore the original configuration of the beach as nearly as possible.

Right-hand page
Preparing a pool for oil softening and subsequent hydrocleaning.

1. General view of an affected beach.
2. Construction of pool walls using cobbles.
3. Fitting plastic and geotextile linen.
4. Finished pools.
5. Hydrocleaning of softened oil on cobbles.
6. Return of clean cobbles.

3.5 Making a pool with added nutrients

This is a variant on the previous method based on bacterial biostimulation.
Following manual removal of oil from the surface and between the cobbles, pools are constructed as in the previous example, filled with cobbles and flooded with sea water. In this case nutrients are added (nitrogen and phosphorous base with oligoelements) to stimulate and accelerate degradation by the petroleolytic bacteria in the medium.
This procedure speeds up degradation and softening so as to cut down the time required for other mechanical techniques.


Manually cleaning up oil on a pebble beach.

3.6 Movement of cobbles to the surf zone

In some cases the oil-impregnated cobbles can be moved to the surf zone to speed up the natural cleaning process. This movement of cobbles may be called for at pebble beaches with a high natural recovery rate, i.e. where the cleanup power of the sea is high and where the average diameter of the shifted cobbles does not generally exceed around 50 cm.
If moving surface cobbles poses a risk of

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erosion of the beach base, oil-stained cobbles will have to be replaced with clean ones of comparable diameter from intertidal zones of the beach. If the base substrate is not erodable, cobble replacement is not necessary and the beach profile will be restored by wave action.
Below is a brief description of the different variants of this cleaning method.

3.6.1 Manual movement of cobbles to the surf zone without substitution

This method can generally be used in small pebble beaches with intense activity, where access is difficult for machinery and the average pebble diameter is under 30 cm. These zones should first be cleaned manually to remove the top layer of oil.
If oil is found in the beach substrate (percolated residue), these buried layers will be cleaned manually while at the same time the cobbles are moved to the lowest intertidal level to speed up the natural cleaning process.
As the cobbles are removed and the substrate is uncovered, the layer of oil that has accumulated on the base is removed. This operation should be undertaken by teams of between 5 and 10 people working manually with crow bars and trowels.
The ultimate objective is to remove as much oil as possible while at the same time moving cobbles to a lower intertidal level to facilitate the natural erosion process which will gradually eliminate the fuel oil residue.

Methodology for moving cobbles to the wave line

1. General view of inactive beach affected by fuel oil.

2. Transport of cobbles to the surf zone using light duty tracked vehicles.

3. Washing of cobbles by wave action.

4. General view of the beach after cleaning action.

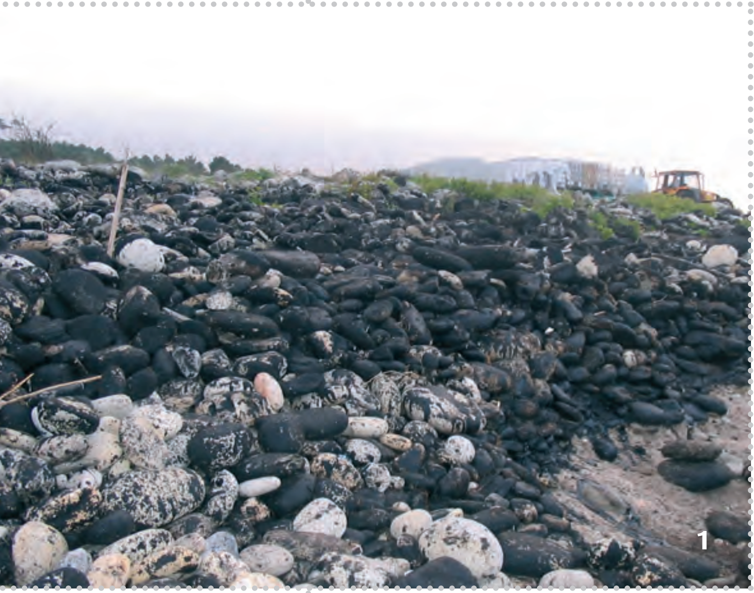

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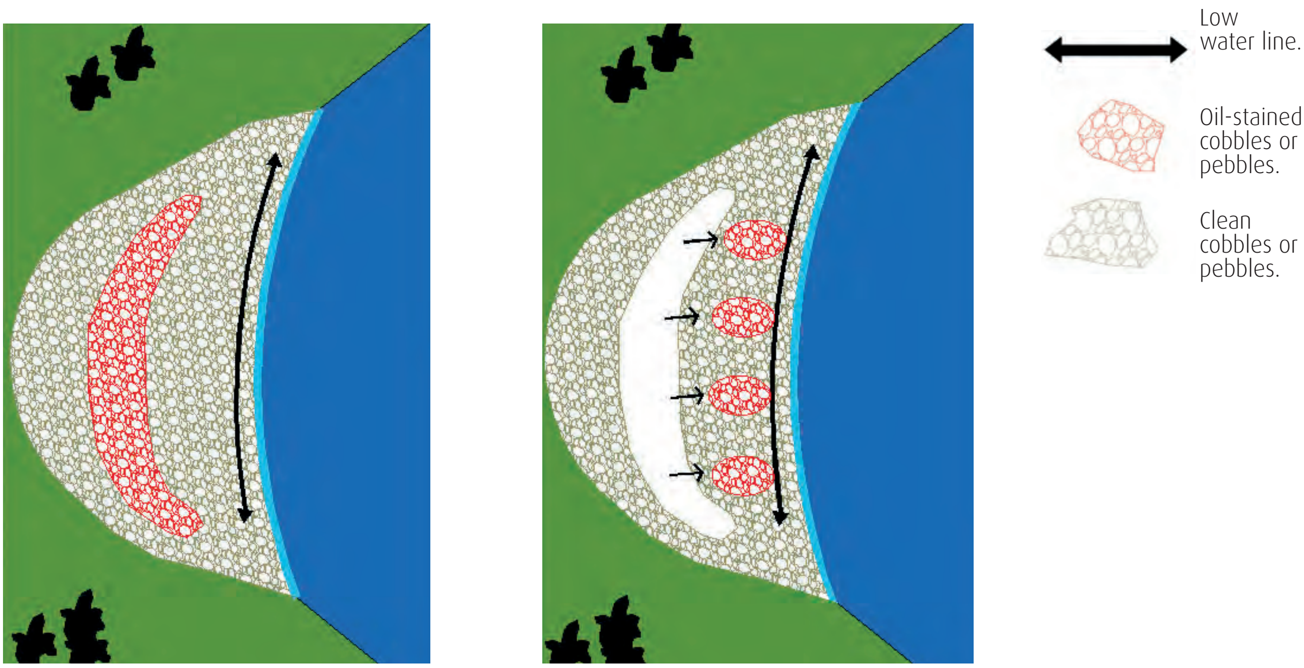
Diagram No. 1: Pebble beach showing movement of cobbles to the surf zone without replacing cobbles. In the drawing on the left, there is initially one active zone (the oil-contaminated area of the beach is marked in red). On the right, the groups of oil-stained cobbles have been placed manually at the surf zone, and the substrate underneath the cobbles is temporarily uncovered until the movement of the sea rearranges them naturally.

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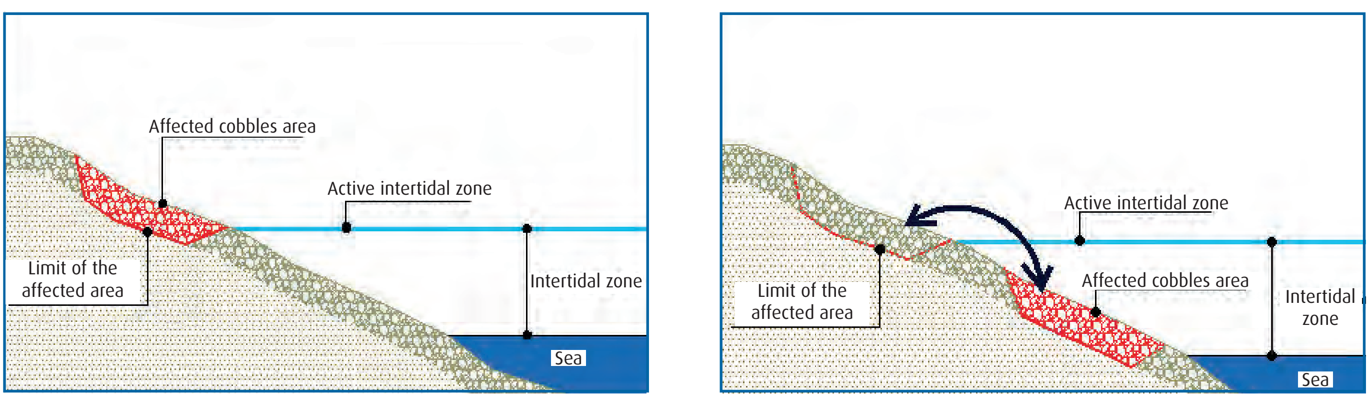
Due to the thrust of the tides, the cobbles tend to resettle further up the beach, thus re-establishing a balance.
The natural washing process of the cobbles has to be monitored over time, as does the recovery of the original beach profile, so that if necessary further action can be taken to replace the cobbles.

3.6.2 Movement of cobbles to the surf zone and replacement of the oil-stained cobbles with clean ones

Certain stretches of some pebble beaches are protected from wave action by a rocky shelf which dissipates wave energy. Many pebble beaches also have a large inactive zone which is not subjected to sea action under normal circumstances, in some cases exhibiting a fossil grade bearing witness to a past sea level that was several metres higher than it is now.
These characteristics dictate the works to be conducted, and machinery must not be used in these zones.
In any case, on such beaches it is suggested to enlisting geomorphologists or geologists to guide the coordinator or group leaders in deciding what sort of action will produce the least impact on the medium.
As in the previous case, percolated fuel will be removed while at the

Diagram 2: Cross-shore view of movement of oil-stained cobbles from the high tide line and replacement with clean cobbles from the active intertidal zone. Oil remaining on the substrate of the affected area must be removed manually before the clean cobbles are put in place.

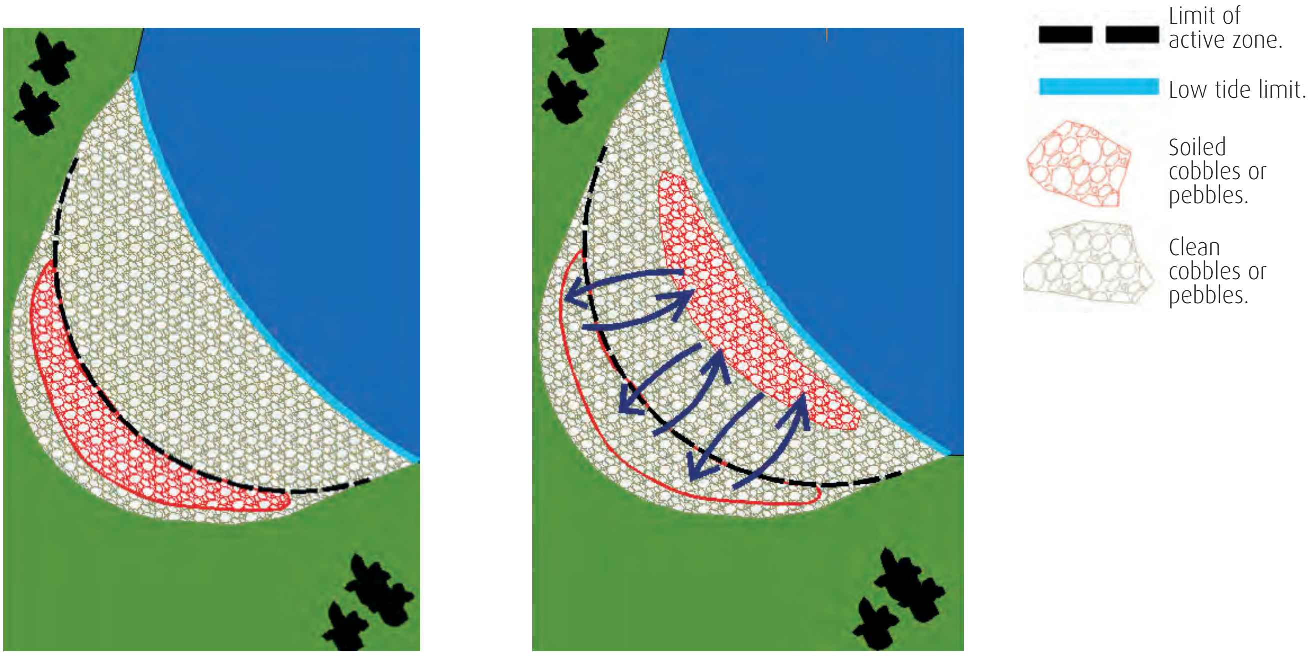


same time oil-stained cobbles are moved manually to the surf zone. In order to increase the friction on the cobbles produced by wave action, an artificial berm will be built up to achieve an angle of incidence against which waves will break with greater energy.
In the areas chosen to group the cobbles there should not be any rock-bordered screen which would tend to dissipate wave energy. Light duty tracked vehicles can be used to shift the cobbles. A ramp made of wooden pallets could be useful to facilitate vehicle movement about the beach.

3.6.3 Mechanical movement of cobbles to the surf zone and replacement of oil-stained cobbles with clean ones

In the case of larger pebble beaches than in the previous example, machinery may be used, conditions permitting, to move the cobbles to the surf zone. Sampling should be carried out beforehand to make sure

Diagram 3: Representation of a pebble beach zone where soiled cobbles have been shifted to the surf zone and replaced by clean ones. An inactive or semi-active area is shown on the left (red shading indicates the beach area polluted with fuel oil). On the right the oil-stained cobbles are grouped at the surf zone; these have been replaced by clean ones of comparable size from intertidal parts of the beach. This method keeps the beach substrate covered thus preventing unwanted erosion.



that there are not large quantities of oil under the cobbles. If necessary, this oil must be removed manually before the cobbles are moved, or some other cleaning method may be employed, such as washing of cobbles in containers.
This procedure can be used at especially active polluted pebble beaches where thickness of the cobble layer is less than one metre and cobble diameters do not exceed 25 cm, provided that the action is not detrimental to any inactive zones.

The following steps should be taken when employing this mechanical cleaning method:

- Removal of clean cobbles from the low-water line and assembly in the supratidal zone.
- Movement of contaminated cobbles froms the supratidal zone to the low-water line using machinery.
- Arrangement of clean cobbles in the zones from which the oil-stained ones were removed, covering up the beach substrate.

3.6.4 Mechanical movement of cobbles to the surf zone, without substitution

In the case of cobble beaches of similar characteristics to the previous case, mechanical movement of cobbles without substitution is an option provided that there is no danger of substrate erosion.

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Suitable equipment must be used to move the cobbles. The use of bulldozers is completely out of the question in view of the excessive substrate erosion caused by driving operations.
In general, these pebble or mixed beaches (sand and pebbles) afford easy access to machinery. In very active zones where there is danger of erosion or slope degradation, oil-stained cobbles should be replaced by clean ones in order to protect the slope against wave erosion.
After such action, beach profiles typically recover their shapes quite quickly, especially during the winter months. Depending on the lithology, the size of the beach and the severity of the pollution, it may be necessary to undertake movements in successive actions.

3.7 Other action proposals

3.7.1 Washing of cobbles at plant facilities

In the technical literature specialized on treatment of these kinds of sites a procedure for cleaning small stones is cited, consisting in transfer by truck for cleaning at treatment plants. Once washed, the stones are returned to their place of origin.
This method is proposed as an alternative to moving the cobbles to the low-water line in accessible zones where wave energy is low and stones are small, and where there is also special environmental interest or shellfish production given the proximity of a bank of molluscs or other species.

Mechanical movement of cobbles

1. Oil-stained cobbles on the upper part of the beach.

2. Moving cobbles with a backhoe.

3. General view of the beach after cobble washing by natural wave action.

3.7.2 Flooding of affected zones to wash away pollution

This procedure, which should be used in combination with absorbent barriers to prevent pollution spreading to other areas, is only effective for materials impregnated with hydrocarbons and provided that a high flowrate of water can be achieved, which is not always possible in areas that are difficult to access.
This method basically entails injecting water at the upper margin of the affected zone during low tide in order to flush away hydrocarbon residue deposited among the cobbles. The flow of water should be controlled, i.e. increase or decreased depending on how fast the water flows among the stones.
This procedure is not suitable for high-viscosity oil.

4. COMPREHENSIVE BACKGROUND INFORMATION REGARDING THE WORK AREA. POLLUTED AREA FACT SHEET

In order to select the most suitable cleaning method for a polluted area, it is essential to obtain all available background information. In this case, the more detailed and complete the information is, the better the results will be.
The following aspects must be covered:

- **Geographical location**
  Cartography, road maps and photographs of each worksite must be available so as to be able to pinpoint the exact location and establish the best itineraries for the transport of personnel, machinery and waste.

- **Access conditions for cleanup personnel and machinery**
  It is necessary to know the type of access conditions at each polluted pebble beach without losing sight of other vital factors such as any danger involved, the type of machinery, if oil removal will present difficulties, etc., because it is largely this information that will determine which decontamination method is chosen.

- **Geomorphology and littoral dynamics of the pebble beach**
  It is extremely important to obtain a description of the morphology of the cobble beach, including information regarding surface area, type of substrate, cobble size, beach slope, whether the cobbles are evenly distributed as regards location and size, etc. A single beach can have different zones, so that different cleanup methods may be selected to adapt to local variations. Information regarding the littoral dynamics of a pebble beach is essential. Knowledge of the direction of wave incidence, the occurrence and characteristics of storms or variations in tidal range can all help to make the treatment more effective.

- **Ecology, geomorphology, fauna and flora**
  This background information should include all ecological aspects specific to each area. It is especially important to know the level of protection and degree of conservation of each site and likewise the geomorphologic characteristics and exact location of plant and animal species to prevent any negative effects of cleanup activities, given that most pebble beaches are classified as Habitats of Community Interest and may be home to or in the vicinity of areas inhabited by unique or threatened species or species in danger of extinction.

- **Type and degree of pollution**
  A preliminary report should be drafted on each polluted site describing the type and degree of pollution.

- **Scientific-technical consultation: ecology, geomorphology, microbiology, zoology, botany**
  With a view to further supplementing background information which is vital prior to initiating any type of cleanup activity, it is essential to enlist specialists in the variety of environmental aspects that have a bearing on the future cleanup work. A study of these aspects and a knowledge of the immediate environment can be very helpful in the taking of decisions.
  To that end it is essential to consult all available sources: universities, scientific institutions, government offices, environmentalist associations or other individuals and institutions possessing knowledge of the subject.

In Annex I of this document there is a Polluted Area Fact Sheet which contains all of the information gathered on a specific work area and necessary to assess the pollution level of a specific stretch of coastline.

5. SELECTION OF THE MOST SUITABLE METHOD. IMPACT MATRIX AND CLEANUP METHODS

Once all the information available on the worksites has been collected, that information must be placed alongside the different cleanup methods with a view to selecting the most appropriate one for each case.
It is therefore very helpful to draw up a table or matrix which reflects the impact that each of the possible actions at each worksite will have on the environment. The international technical literature offers a number of different tables of this kind.
Annex II of this document includes the Impact and Cleanup Method Matrix which was compiled and adapted to fit the characteristics of Spain's Atlantic coast and other major aspects drawn from the experience built up in the aftermath of the Prestige spill. This working tool will make it possible to assess the different aspects relating to cleanup methods and working environments with a view to selecting the most suitable action procedure.

HANDBOOK 6

6. WORK ORGANIZATION AND MINIMIZATION OF ENVIRONMENTAL IMPACT DERIVING FROM CLEANUP ACTIVITIES

Once a diagnosis of the effect of the pollution has been made by means of the Fact Sheets and decisions taken in terms of the most suitable cleanup alternative for a specific area using the Impact and Cleanup Method Matrix, the next step is to optimize the work and minimize any side effects that a given action may have on the environment.

Following is a list of recommendations to be borne in mind when undertaking cleanup activities, in order to reduce the impact as far as possible. This includes a set of general recommendations to consider when undertaking any type of initiative, and other specific ones tailored to each of the cleanup methods for pebble beaches.

6.1 General recommendations

- **Delimitation of the contaminated zone. Routes for personnel and machinery**
  In order to protect non-polluted zones, it is of the essence to establish routes for use by personnel and machinery, and to insist that they must be used to diminish the possibility of secondary pollution from cleanup works.

- **Delimitation of sensitive areas for flora and fauna**
  If there are any sensitive or threatened plant or animal species in the vicinity of the worksite, once their location is known that area must be roped off, cleanup personnel informed and transit through the area prevented. If an area of this kind is in need of cleanup, this work should be undertaken by properly

Roping off of a sensitive area.

trained personnel, taking care to protect sensitive species at all times. To refrain from taking any action at all is also an option to consider when faced with sensitive species of flora and fauna.

- **Personnel and machinery decontamination zones**
  Personnel and/or machinery decontamination zones must be set up in the vicinity of each worksite to minimize the possibility of secondary pollution. These areas, properly roped off and covered with geotextiles and plastic liners, should be equipped with containers for polluted material and Personal Protection Equipment (PPE). If it is considered necessary, another delimited zone can be roped off for the decontamination of machinery which has been in direct contact with the fuel.

- **Waste storage areas**
  Collection points for waste containers or tanks must be properly fenced off and protected with geotextiles and plastics to prevent waste from the containers from seeping down into the substrate.

6.2 Specific recommendations

6.2.1 Manual cleaning

As mentioned earlier, this is the most appropriate method for pebble beach cleanup, given its effectiveness and low environmental impact. But even so, there are a number of impact minimization measures that must be considered, especially in areas with a special or sensitive geomorphology.

Cleanup consists of directly removing fuel residues by hand or with the aid of trowels, spatulas and other tools. In the case of highly contaminated areas, it will suffice to manually remove the fuel residue on and between the cobbles. The impact caused by cleanup personnel will be minimal, provided that proper measures are taken to delimit areas and prevent secondary pollution.

In cases where petroleum residue has percolated down past the stones to the substrate, cobbles must be shifted in order to remove it. It is recommended to open a furrow (a trench of sorts) perpendicular to the low-water line and cleaning the entire polluted pebble area from that line. Care must be taken to ensure that cobbles for manual cleaning which still have oil adhering are not mixed with clean cobbles.

The impact of this type of manual cleaning of percolated fuel can be significant, especially in the case of inactive pebble beach areas, and therefore very special care must be taken.

- **In active zones of pebble beaches**, i.e. zones where waves are constantly shifting cobbles, the latter are typically small and easy for cleanup personnel to handle, although the machinery can also be employed, where viable, to move the heaviest cobbles and thus facilitate manual cleaning. Care must be taken that the backhoe scoop does not erode the beach substrate. Care must likewise be taken not to leave the base of the pebble beach uncovered, and to cover it up again once the substrate and stones have been properly cleaned.

- **In inactive zones of pebble beaches**, i.e. zones of particular geomorphologic value which are beyond the reach of the sea, only manual cleaning must be undertaken, taking care to disturb the beach as little as possible and restore the cobbles to their original positions after removing fuel. In general terms, cleaning under cobbles should only be done where they can be moved manually or with the help of crowbars, provided that this does not alter their original layout. Machinery must only be used to help move certain cobbles in exceptional cases and under specialist supervision.

6.2.2 Direct mechanical collection

As was already pointed out in earlier sections, this cleanup method is appropriate solely in areas with very high concentrations of pollutant in the form of large pools of fuel that can easily be reached with machinery.

The impact of machinery on the environment should be kept to a minimum, by establishing strict access routes to the pebble beach, setting up a decontamination zone and above all ensuring that the scoops collect the fuel directly from the pools where it has accumulated without under any circumstances disturbing the rock surface.

Cleanup personnel decontamination zone.

In these cases, the machinery itself may very well be the origin of secondary pollution given that it is in direct contact with large quantities of pollutant, so that it is extremely important to rope off a decontamination zone (equipped with a hydrocleaner and geotextile material to collect liquid residue).

When there are large accumulations of fuel in a specific area that cannot be reached with machinery, the possibility of opening up access paths may be considered to facilitate cleanup and the removal of residue. Once these actions are concluded, the surrounding environment must be restored by removing all material from the paths and facilitating regrowth of vegetation.

6.2.3 Moving cobbles mechanically

This type of action is suitable in the case of pebble beaches with the following characteristics:

- Good access.
- Absence of geomorphologic characteristics that would render such action inadvisable.
- Cobbles of average diameter under 30 cm.
- A high rate of natural cleanup by wave energy (highly active pebble beaches).

Bulldozers or the like should not be used for this sort of work as they indiscriminately scour the substrate of a cobble beach, altering natural slopes and the edaphic structure of the substrate. It is therefore recommended that cobbles be moved with machinery that scours the substrate as little as possible.

When fuel has seeped under the cobbles, the polluted part of the substrate should be cleaned manually at the same time as the cobbles are moved with machinery.

On pebble beaches where this type of action is undertaken, if the average diameter of the cobbles is 30-40 cm it is further recommended that the oil-stained cobbles be replaced with clean ones from the intertidal or lower supralittoral zone, otherwise the substrate would be left bare and exposed to erosion.

It is very important to conduct operations such as these on the days prior to spring tides and/or expected storms. In this way cleanup will be more effective and the cobbles that have been moved can be more easily and quickly restored to their original natural position.

This action is not recommended for inactive beaches or areas which are sheltered by rock formations so that wave action cannot clean the contaminated cobbles and restore then to their original position.

To achieve greater cleaning efficiency using this method, it is recommended that the cobbles be grouped to form ridges perpendicular to the low-water line. This increases their resistance to movement, thus increasing the chances of more effective cleaning. Once the cobbles have been shifted, the process of natural cleaning and relocation should be monitored.

While these operations are going on, it is essential to seek the advice of specialists in geomorphology and littoral dynamics who can provide information and essential instructions regarding any cleanup method proposed on pebble beaches.

6.2.4 Moving cobbles manually

This is appropriate for pebble beaches (or active zones thereof) with the following characteristics:

- A high rate of natural cleaning.
- Average cobble diameter under 40 cm.
- Difficult access for machinery.
- Special and sensitive geomorphologic characteristics which render the use of heavy machinery impracticable or inappropriate.

Although the moving of the cobbles to the wave line is essentially manual labour, it can be assisted with a light duty tracked vehicle.
In the active zones of pebble beaches with special geomorphologic characteristics, it is recommended always to replace oil-stained cobbles with clean ones from the intertidal zone. This keeps the substrate protected from sea erosion.
In cases where fuel is buried under the cobbles, this substrate should be cleaned up as the cobbles are moved manually.
As in the foregoing case, it is very important to undertake actions of this kind on the days before spring tides or expected storms to make the treatment more effective.
In some areas where this cleanup method is used, it will be necessary to perform this cobble moving process several times in succession in order to achieve acceptable results. The number of times will depend on the lithology and slope of the beach, wave energy and other local variables.
As in the previous case, to achieve greater cleaning efficiency using this method, it is recommended that the cobbles be piled in small ridges perpendicular to the low-water line.

Detail of manual cleaning of a pebble beach and manual moving of cobbles.

In the case of both mechanical and manual moving of cobbles to the surf zone, specialists in geomorphology and littoral dynamics should always be enlisted to provide advice.

6.2.5 Hydrocleaning

This method is recommended for areas with medium to low pollution levels, on rocky beds and where there is a continuous film of fuel on rock formations. A specific procedure has already been developed for these cases (see the relevant chapter) which defines all aspects related to the treatment of rock substrate with high-pressure water jets.
All the instructions provided by the "Procedure for the cleanup of rocky zones and infrastructures by washing with pressurized water jets" (see Handbook No. 3) in this document should be followed, especially as regards minimizing the impact of high pressure water on the weathered surface of the rock (appropriate distance from which to direct the water jet, temperature, pressure, etc.). It is further recommended that abundant geotextile, blankets and absorbent barriers be used to collect the contaminated effluent and to cover all non-contaminated surfaces and surfaces that have already been hydrocleaned.

6.2.6 Bioremediation (biorecovery)

This method is recommended for pebble beaches where the degree of pollution is low. Its effectiveness derives from the enhancement of natural hydrocarbon biodegradation processes by means of petroleolytic bacteria which use it as a carbon source and break it down.
Bioremediation is advisable when mechanical collection methods are no longer effective. The method basically entails the adding of auxiliary nutrients (N, P, Fe, etc.) and other bacterial growth activators that favour the growth of autochthonous petroleolytic species, in the affected areas. As in the case of hydrocleaning, there is also a specific protocol for this treatment found in Handbook No. 7 of this document: "Procedure for action using bioremediation techniques in rocky environments impregnated with fuel-oil".

Other methods
Other methods also found in the international technical literature include cobble washing at plant facilities or the flooding of areas affected by washed-in contaminant material. These are less commonly used but should also be borne in mind for certain areas and specific actions when all other cleanup options are ruled out.

ANNEX I

Contaminated Area Fact Sheet

(*) Scale for estimation of the amount of fuel on the coastline.
Traces (not shown): Fuel covers less than 1% of the examined surface area.
Sporadic: Between 1 and 10% of examined surface area affected.
Patchy: Between 11 and 50% of examined surface area affected (estimate %, see scale).
Broken: Between 51 and 90% of examined surface area affected (estimate %, see scale).
Continuous: Over 90% of examined surface area affected.
If the fuel is only found on a limited part of the area visited, an estimate will be made of the surface area in relation to the total area of the zone, and the scale will be applied only to the part containing fuel. The part affected will be marked on the corresponding sketch.

(**) Thickness of the oil layer.
The term Pooled Oil (covered) describes a situation in which there is a large quantity of fuel forming large pools or sheets so that the beach is completely or partially submerged in that pool of oil.
The term Cover (puddles), describes a situation in which there is a large amount of oil forming puddles or continuous sheets between the cobbles; the difference between this and the term described above is that the surface structure of the cobbles is clearly visible.

Sporadic	Patchy			Broken			Continuous
1 – 10 %	11 – 50 %			51 – 90 %			91 – 100 %
10 %	20 %	30 %	40 %	60 %	70 %	80 %	90 %

Fuente: OWENS D., Ed. Woodward – Clyde consultants (Alaska), 1994)

CONTAMINATED AREA FACT FORM

ACCIDENT IDENTIFICATION
TYPE OF CONTAMINANT

OBSERVER		LOCATION OF THE AREA		TYPE OF COASTLINE	
Name:		Name:		Cliff area	
Date:		ID code:		Cliff with loose stone	
Time:		Town:		Loose stone	
Time of high tide		Province:		Beach with loose stone	
Observations:		Observations:		Man-made	
				Observations:	

TYPE OF ROCKY SUBSTRATE AND APPROXIMATE SURFACE AREAS			ACCESSIBILITY		REMOVAL OF OIL	
Solid rock	%	m^2 (flat surface area)	Paved access		Possible	
Cobbles > 1 m diameter	%	m^2 (flat surface area)	Pedestrian access		Difficult / Human chain	
Cobbles 1 – 0.5 m diameter	%	m^2 (flat surface area)	No access		Helicopter required	
Cobbles < 0.5 m diameter	%	m^2 (flat surface area)	Dangerous pedestrian access		Impossible	
Observations:			Access by boat		Other / Observations:	
			Other / Observations:			

DIMENSIONS OF THE CONTAMINATED AREA (MAP)			CONTAMINANT COVERAGE (*)		THICKNESS OF THE CONTAMINANT LAYER (*)	
Length	m	Observations:	Continuous (>90% affected)		Pooled Oil	
Width	m		Broken (51-90% affected)		Cover	
Flat surface area	m^2		Patchy (11-50% affected)		Coat	cm
Entire stone beach area			Sporadic (1-10% affected)		Stain	
Note: if more than one stretch is affected, a separate sheet will be used for each stretch.			Trace (<1% affected)		Film – iridescent sheen	
			Observations:		Observations:	

ACTIONS UNDERTAKEN PREVIOUSLY	RECOMMENDED ACTION	COMMENTS AND OTHER ASPECTS

ANNEX II

Impact and Cleanup Method Matrix

Instructions for completing the Impact and Cleanup Method Matrix.
1) with the help of the Contaminated Area Fact Sheet which has already been filled out, indicate the limiting factors which could influence the implementation of each of the different cleanup methods shown in the table. Mark the appropriate box with an "X" if there is a specific limiting factor which would rule out or negatively influence a particular action, except in the column marked "no action", where an "X" should be marked in the corresponding box if the factor calls for not taking any action at all. Once the boxes have been filled out, the summation of the limiting factors for each cleanup method is computed.
2) mark the recommended cleanup methods with an "X" according to the degree of pollution in the zone, taking into account the limiting factors identified in step one. The cleanup methods with the fewest limiting factors will be the most recommendable and appropriate for the worksite into consideration. On the other hand, those methods with the most limiting factors will be the least recommendable for that worksite.

(*) Degree of pollution;

- High: using the same terminology as on the Polluted Area Information Sheet, this term describes situations of "Pooled Oil" or "Cover" and situations of "Continuous" (>90%) pollutant coverage.
- Medium: using the same terminology as on the Contaminated Area Information Sheet, this term describes situations of "Coat" or "Stain" and situations of Broken (51-90%) or Patchy (11-50%) pollutant coverage.
- Low: using the same terminology as on the Contaminated Area Information Sheet, this term describes situations of "Film–iridescent sheen" and situations of Sporadic (1-10%) or Trace (<1%) pollutant coverage.

(**) Example: Pebble beach 1: the explanation of the marked boxes is as follows:

No Action
Pebble beach 1 presents special geomorphologic characteristics dating back 120,000 years; <u>this uniqueness is the factor determining the recommendation for "No Action" in light of the low degree of contamination</u>.

IMPACT AND CLEANUP METHOD GRID

ZONE		LIMITING FACTORS AND RECOMMENDATIONS		NO ACTION (*)	POSSIBLE CLEANUP METHODS: DIRECT MECHANICAL COLLECTION	MANUAL CLEANUP	MECHANICAL MOVING OF STONES	MANUAL MOVING OF STONES	HYDRO-CLEANING BIOREMEDIATION
BEACH 1	LIMITING FACTORS	INACCESSIBILITY / DANGER		X	X		X		
		GEOMORPHOLOGY / LITTORAL DYNAMICS			X	X	X	X	
		SPECIFIC VALUES FLORA / FAUNA			X		X		
		TRANSPORT OF CONTAMINANT							
		TIDE REGIME			X	X			X
		SHELLFISH / FISHING INTEREST					X	X	X
		TOTAL LIMITATIONS		1	4	2	4	2	2
	RECOMMENDATIONS	DEGREE CONTAMINATION (*)	HIGH (*)			X			
			MEDIUM (*)			X		X	
			LOW (*)	X				X	X
NAME OF BEACH	LIMITING FACTORS	INACCESSIBILITY / DANGER							
		GEOMORPHOLOGY / LITTORAL DYNAMICS							
		SPECIFIC VALUES FLORA / FAUNA							
		TRANSPORT OF CONTAMINANT							
		TIDE REGIME							
		SHELLFISH / FISHING INTEREST							
		TOTAL LIMITATIONS							
	RECOMMENDATIONS	DEGREE CONTAMINATION (*)	HIGH (*)						
			MEDIUM (*)						
			LOW (*)						
NAME OF BEACH	LIMITING FACTORS	LIMITING FACTORS							
		INACCESSIBILITY / DANGER							
		GEOMORPHOLOGY / LITTORAL DYNAMICS							
		SPECIFIC VALUES FLORA / FAUNA							
		TRANSPORT OF CONTAMINANT							
		TIDE REGIME							
		SHELLFISH / FISHING INTEREST							
		TOTAL LIMITATIONS							
	RECOMMENDATIONS	DEGREE CONTAMINATION (*)	HIGH (*)						
			MEDIUM (*)						
			LOW (*)						

Direct Mechanical Collection
This cleanup method presents 4 limiting factors for pebble beach 1: very difficult access for heavy machinery to a large part of the beach surface; its geomorphologic characteristics, which are of great ecological value, would be significantly damaged by this cleanup method; access of heavy machinery would damage part of the supralittoral flora; and the tide regime would complicate the operation tremendously at high tide and during spring tides. These 4 limitations mean that this cleanup method is not recommended in any case (none of the recommendation boxes should be marked with an "X").

Manual cleanup
Two limitations were checked for this cleanup method, which has the least negative environmental impact: the tide regime may affect cleanup works especially at spring tide and during storms, complicating or preventing manual cleanup work. Moreover, given that this is a well preserved pebble beach with special geomorphologic characteristics, damage could be done if manual relocation of the cobbles is not done properly. However, although the Geomorphology box is marked, if suitable corrective measures are implemented, that impact could be greatly reduced. For these reasons, manual cleanup is recommended when the pollution level is High or Medium.

Mechanical movement of cobbles
This case is similar to that of Direct Mechanical Collection, with the added factor that this is a popular fishing and shellfish harvesting area (the fuel washed from the cobbles by the natural action of the sea could have a negative effect on local fishing and shellfish harvesting) and it is therefore not recommended in any case.

Manual movement of cobbles
This method presents 2 limiting factors marked on the table; the washing of the cobbles moved to the surf zone could affect local fishing or shellfish harvesting and could also alter the beach's unique geomorphology; however, the application of a series of corrective measures could significantly minimize the negative impact on the geomorphologic structure of the beach. This cleanup method is therefore recommended for specific parts where there is medium to low pollution, provided that a series of corrective or impact mitigating measures are implemented.

Hydro-cleaning
There are 3 limitations associated with this method –the one indicated above in respect of the unique geomorphology of the beach, the tide

regime which could hinder hydrocleaning on certain areas of solid rock formations and a third related to the shellfish harvesting in the area (effluents from rock cleaning could have an impact on commercial species). This last limiting factor could be reduced if the proper impact minimization measures are implemented. This method is therefore recommended for the treatment of specific parts of the pebble beach affected by medium to low levels of pollution.

Bioremediation

There are 2 limiting factors: the tides, which could wash away the oleophilic substances applied to certain zones, and the possible negative impact of introducing an excessive quantity of nutrients (marine eutrophication) in a fishing and shellfish harvesting area. For these reasons, the use of this method is recommended only in conditions of low-level pollution.

CONCLUSIONS

Summing up, in the case of pebble beach No. 1, manual cleanup is the only method recommended in the event of high-level pollution; in the event of medium level pollution, manual cleanup and hydrocleaning of solid rock formations with manual transfer of oil-stained cobbles to the surf zone is recommended; in the event of low level pollution, manual transfer of cobbles to the surf zone, hydrocleaning of solid rock formations, bioremediation and no action at all would all be recommended.

HANDBOOK 7

Procedure for action using bioremediation techniques in rocky environments impregnated with fuel-oil

1 INTRODUCTION. IMMEDIATE BACKGROUND TO THIS WORK

The literature on bioremediation is, at present, far more abundant than it is conclusive. This is due, at least to a great extent, to the variety of possible outcomes when the various resources that are habitually included in the notion of bioremediation are combined with the diversity of conditions that can occur in the target areas. We would note in this connection that the information set out in the following pages comes from a concrete experiment, consisting in assays of various bioremediation techniques on supratidal rocks on the island of Sálvora which had been affected by the *Prestige* oil spill, followed by the application of the technique that proved most effective in other similar areas of the Atlantic Islands of Galicia National Park, the Costa de Morte and other sites on the cantabrian coast.

The assays on Sálvora and their application in other areas of the National Park, and the applications on the Costa da Morte and the cantabrian coast, were promoted by the Ministry of the Environment and subsequently maintained by the Centre for the Prevention and Combating of Marine and Coastal Pollution (Ministry of the Presidency). They were carried out by three groups from the Instituto de Investigacións Mariñas (CSIC, Vigo). The Waste Recycling and Upgrading group carried out the treatments, the follow-up and assessment of effectiveness and all the samplings entailed in all the other actions; the Mollusc Pathology and Energy Physiology groups used wild mussel as the indicator organism to assess aspects relating to biosafety of treatments, which were found to be innocuous in all cases.

Annex 1 to this procedure summarizes the purpose and the results of the assays conducted on the island of Sálvora from which it was determined what type of treatment was most effective on rocky sites.

2. BASES OF BIOREMEDIATION

Bioremediation may defined in very general terms as the use of living beings to restore the natural balance of matter in an area disturbed by human activity. In the specific case of bioremediation applied to oil pollution, there are two elements to be considered.

- **Fertilization**

  Oil pollution in principle produces an overload of organic carbon in the medium. However, we would qualify that by noting that this carbon is not quite the same as the carbon found in other organic nutrients. This is firstly because oil contains numerous components that act as chemical stress signals for many biological entities, which often respond by inhibiting various metabolic mechanisms involved in the degradation of exogenous substrates. Secondly, hydrocarbons are highly reduced compounds (hydrogen-rich) which require a plentiful oxygen supply for degradation in aerobic conditions (degradation in anaerobic conditions is slower). Also, many hydrocarbons can only be assimilated at appreciable rates in the presence of other organic carbon sources (co-substrates). And finally, their poor solubility in water detracts from their bioavailability —that is, their capacity for incorporation to the dynamics of metabolism— which is non-existent in the case of components of large molecular size such as resins or asphaltenes. All these characteristics explain the high metabolic tenacity of oil, that is its overall resistance —in spite of appreciable differences from one fraction to another— to biodegradation processes.

  Nevertheless, there are numerous microorganisms which are petroleolytic (capable, at least in certain conditions, of utilizing petroleum hydrocarbons as food), and therefore it seems reasonable to facilitate their task by providing them with other nutrients to balance their diet. The essential elements for these purposes are nitrogen, phosphorous and to a lesser extent iron (others are available in practically any habitat), so that one obvious procedure is to supply these supplements in the forms present for example in conventional agricultural fertilizers (nitrates, ammonium salts, urea, phosphates). This fertilizing component of bioremediation is essential in all cases.

- **Bioreinforcement**

  If fertilizing assists oil consumption by the microorganisms that colonize a polluted area, it seems reasonable to suppose also that the process can be accelerated by adding a bioreinforcement —that is by seeding known microbial species capable of assimilating hydrocarbons and free of contraindications (biological risks).

  Unlike fertilization, bioreinforcement is of much more limited utility, and its efficacy is highly dependent on the type of substrate that is to be treated.

  Although we mention this technique, experience of bioremediation actions on supratidal rocks shows that in such media bioreinforcements do not significantly improve the efficacy of correctly-applied fertilization.

  In the context of oil spills, both elements of bioremediation action have elicited a number of objections owing to alleged undesirable collateral effects, although the real problems chiefly lie in achieving a reasonable degree of efficacy. Annex 2 lists the criteria normally applied in balance sheets to the use of bioremediation as a technique for cleaning of oil-polluted coastal areas.

3. GENERAL CONSIDERATIONS ON THE USE OF BIOREMEDIATION

The purpose of bioremediation is to speed up the biodegradation of oil in a polluted area without the risk of undesirable collateral affects. This is a resource which simply activates or stimulates natural biological processes, and its effect is achieved by the interaction of numerous factors so that no generic recipe can be established, but these factors must be considered in assessing the efficacy of the treatment. Summarized below are the basic principles that ought to guide the selection of times, spaces, types of pollution, forms of treatment and characteristics of formulations that can be applied in bioremediation actions.

3.1 Slowness of the process

We would note to begin with that bioremediation is a slow decontamination procedure whose action should in principle be envisaged in terms of months. It does have the advantage that the metabolic mechanisms that it activates break down and consume at least part of the hydrocarbons (generally the most toxic fractions) relatively quickly, and unlike other techniques (for instance hydrocleaning followed by removal of leachings with water-repellent tissues) it does not require subsequent transfer of the pollutants to treatment plants. However, it is not appropriate if for specific reasons rapid cleaning is desired.

3.2 Unsuitable when mechanical removal is possible

Because it is slow, bioremediation is also not to be recommended where the coating of oil deposited on the substrate is thick enough that it can be efficiently removed manually or mechanically. In other words, bioremediation is only indicated where manual or mechanical procedures cease to be fully effective, in areas difficult to access for the equipment they require or in the case of light spills. In short, it is a second-choice or a finishing solution.

3.3 Resistance of the different oil fractions to biodegradation

As noted above, the different oil fractions exhibit very different degrees of resistance to biodegradation, or metabolic recalcitrancy. High efficacy cannot therefore be expected in cases of oils with high proportions of heavy fractions (resins and asphaltenes). However, we would stress that oil-based fertilizer formulations combine favourable conditions for microbiotic growth with moderate but persistent dispersant action. This combination helps to remove even the heaviest fuel-oil fractions at significantly higher rates than are achieved in areas not so treated.

3.4 Problems associated with the ageing of oil

When oil ages in ambient conditions, its metabolic resistance augments. This is firstly because the lightest fractions evaporate, disperse and biodegrade faster than the others. And secondly because while the heaviest fractions admittedly degrade slowly as a consequence of solar UV radiation, there are indications that such radiation further increases the proportion of molecular forms that are strongly adsorbed on to silicates, so that they "set" on granitic rocks in much the same way as the materials that are heated for asphalting roads. Bioreinforcement therefore presents a temporal window of peak efficacy which narrows considerably after 3-6 months.

3.5 Problems associated with different types of natural environments

And finally it must be borne in mind that the sites where bioremediation is most successful are generally polluted soils (caused by oil pipeline bursts, spills or leaks from aerodromes and activities connected with the storage and distribution of foodstuffs and the like). In such cases conventional fertilizing, bioenhancers, turning of the earth to form alternating furrow and ridge structures (biopiles) similar to those produced by ploughing, and occasionally injections of air, oxygen or peroxides, all produce estimable effects in a procedure which combines elements of farming techniques and of organic waste composting.

Rocks on the island of Ons (Pereiró area) affected by the *Prestige* spill, after 18 months of exposure to the elements. The pebbly area, which at one time was as much affected as the adjacent fixed rocks, recovered the state of cleanness visible in the photograph in less than two months.

However, the essential factor in this success lies in the nature of the actual soil: a complex, porous material matrix with a large inner surface which lends it a high capacity to absorb and retain water and nutrients and to create microspaces shielded from direct sunlight, which cushion the effects of temperature and ultraviolet radiation. This matrix is moreover normally the site of intense microbial activity, which cooperatively breaks down a large variety of organic structures (some as resistant as cellulose or lignin), further increasing the molecular diversity to the point where it can potentially supply co-substrates that favor the degradation of the most stable hydrocarbons.

In marked contrast to this situation, we need only think of the desert-like appearance of a beach, the bareness of supratidal rocks or the constant washing undergone by a tidal flat, to appreciate that coastal environments lack many of the conditions that make bioremediation an effective solution in terrestrial environments. That is why, in contrast with the results normally achieved in soil treatments, coastal bioremediation has frequently elicited conflicting opinions which, assuming the procedures have been correctly followed, must be put down to the limitations of the areas so treated.

3.6 Superfluous in areas exposed to waves or pebbly areas

Again because it is slow, bioremediation is not very effective in rocky areas exposed directly to the action of the waves, or in areas such as fine or coarse pebble beaches of the kind shown in figure 1 where the force of the water, although slight, is sufficient to roll the rock fragments, which are thus cleaned by the same friction that helps to rounden them.

3.7 Bioremediation suitable for coastal environments

In coastal environments, areas where natural cleaning agents are less effective are in principle the most logical candidates for bioremediation (figure 1). We would note, however, that suitability is not the same as efficacy. In fact there are areas which are highly sensitive to the impact of an oil spill but at the same time present peculiarities which detract from their susceptibility to efficient bioremediation. For instance, tidal flats, which are very sensitive to hydrocarbons but where bioremedies are ineffectually diluted in the water, or supratidal rocks which remain impregnated for lengthy periods of time but which possess very little capacity to sustain microbiotic growth.

3.7.1 *"In-situ"* treatments

Supratidal rocks are undoubtedly the areas where oil remains longest and is most conspicuous: on the coast at Baiona south of the Vigo Estuary, remains of the *Polycommander* oil spill are still visible today after thirty years of exposure to the elements (attached

1. Rocky margins, shelves or quays exposed to wave action.
2. Open beaches of medium to small pebbles.
3. Coarse sand or shingle beaches.
4. Open tidal flats with intense water exchange.
5. Fine sandy beaches.
6. Sheltered tidal flats, with low water exchange.
7. Marshes and similar formations.
8. Sheltered rocky margins, supratidal shelves.

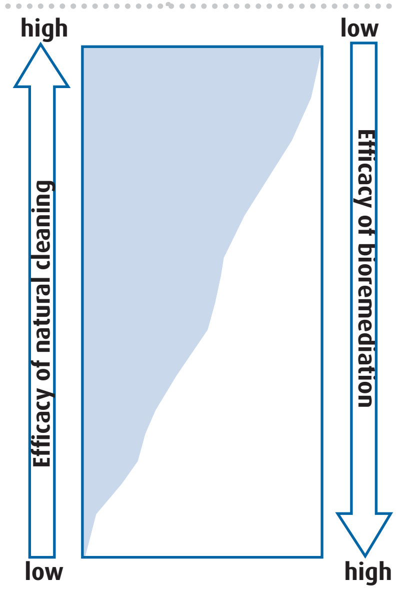
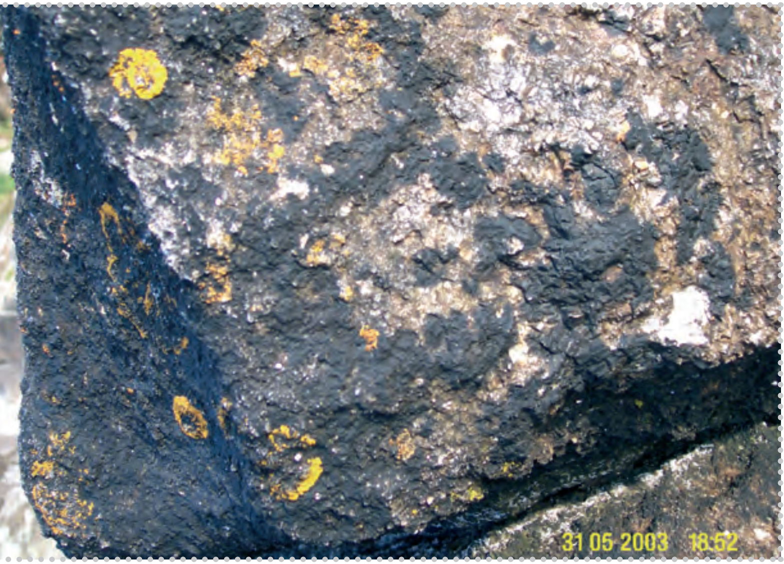


Figure 1: General suitability of bioremediation (in approximate relative terms) in different coastal environments.

photo). The fact is that after a certain time, the oil adhering to the rocks in that way contains only the most stable fractions, which are the least bioaccessible and hence the least toxic: on the rocks referred to at Baiona, lichens of the genus Xanthoria today grow on the oil residue.
At all events supratidal rocks are the typical type of environment that requires *"in-situ"* finishing techniques. The main problem here lies in the fact that not only can earth turning or composting procedures not be used, but rock is a substrate poor in natural microbiota because it is far more hostile to microbial activity than vegetable soils.
As far as bioremediation is concerned, it must be remembered that rocky substrates retain very little moisture, while the materials deposited on their surface are particularly exposed to rain lixiviation, wind scouring and the effects of solar radiation — temperatures as high as 60ºC have been recorded on oil-blackened rocks on Spain's Atlantic coast. Rocky surfaces are therefore very ill-suited to retain fertilizers and bioreinforcements in a viable state, and so the option most to be recommended in such cases is oil-based bioremediation.

3.7.2 *"Ex-situ" treatments*

In areas where there are inter or subtidal fuel-oil deposits, bioremediation is generally not very effective, since —as noted earlier— fertilizers become diluted in the water. Although solutions like immersion of blocks or sacks with slow-release fertilizers are sometimes cited, such a procedure will only be suitable in waters where there is little exchange (tidal lagoons which do not empty completely at low tide), and there is little evidence regarding their real efficacy. Also, in shallow, well-lit waters photosynthetic organisms compete with heterotrophic microbiota for fertilizers without conferring any appreciable capacity to break down hydrocarbons.
There are special situations where it may become necessary to decontaminate intertidal or subtidal sediments. In such cases the solution may be what are called *"ex-situ"* treatments —that is dredging the materials and transferring them to a supratidal location where they can be treated by bioremediation in biopiles in the same way as soils. This kind of operation is generally costly and only warranted, as we said, in exceptional circumstances.
"Ex-situ" treatments may also be the best solution in cases of rock formations among where the oil has seeped down among the interstices and



Remains of the *Polycommander* oil spill after 36 years' exposure to the elements. Note the lichens growing on the oil residue.

formed deposits on the base substrate which are not readily accessible for any treatment. Here, when rock formations are treated and displaced to expose deposits, it is possible to use bioremediation in biopiles. When considering moving such rock formations, the geomorphological values of these formations should be preserved as far as possible.

3.8 Potential use of bioremediation on different coastal margins

As well as bearing on the general suitability of bioremediation, the characteristics of the contaminated areas affect what properties will be required of the most promising bioremediation formulation. Summarized below are the types of action best suited to different types of area.

3.8.1 Earth-covered areas, vegetable soils

- On these soils agricultural fertilizers are recommended in aqueous solutions: oxidized and reduced forms of nitrogen (ammonic and nitric salts, urea), phosphates, iron salts, preferably chelated. With high rainfall it may be advisable to use commercial slow-release preparations. Biopiles, or ridge-and-furrow structures like those produced by ploughing, are a suitable additional solution.

- Oil-based fertilizers can have a biostimulant effect on local microbiota but must be diluted in an aqueous emulsion to prevent clustering or film formation that would hinder aeration.

3.8.2 Intertidal or subtidal sediments

- On this kind of site, any *"in-situ"* addition of bioremediating products is generally ineffective.

- In special cases it may be possible to treat the materials off-site at a supratidal location, applying fertilizers according to the criteria summarized in the foregoing section for soils.

3.8.3 Sandy areas

- On these kinds of sites bioreinforcement is very ineffective or not effective at all, particularly on beaches because the substrate is very hostile to microbiotic growth.

3.8.4 Rocky areas

- On supratidal sites where there is no natural mechanical action, bioremediation should be applied using oil-based fertilizers, which are better than water-based products for many reasons. Neither water-based fertilizers —even supplemented with absorbent and adsorbent materials to facilitate retention— nor bioenhancers are effective to any significant extent. Generally speaking, the most favourable conditions in which to apply bioremediation techniques on these kinds of sites are:

- Areas sheltered from the mechanical action of the sea or where this only reaches in special conditions (strong tides, gales). Nevertheless, the use of bioremedies should be avoided in intertidal zones (including seldom-reached zones where oil may remain for a relatively long time), since even oil-based fertilizers are easily washed away.

- Light layers of fuel oil, where manual or mechanical cleaning is inappropriate or inefficient.

- Areas polluted not more than 3-6 months prior to commencement of the procedure, to avoid problems associated with ageing of the oil.

- Surfaces impregnated with fuel oil residue in which the light fractions predominate over the heavy fractions (saturated and aromatic hydrocarbons in higher proportions than asphaltenes and resins).

- Proximity of the polluted area to terrestrial environments (woodland, scrub), as the microbiota associated with such environments enhances biodegradation processes.

3.8.5 Shingle and pebble beaches

With increasing particle size of the materials, from sand to up to pebbles, if such areas are sufficiently exposed for the mechanical action of the sea to move the materials —even a little— this abrasive action effectively cleans, so that any further treatment, such as bioremediation, is unnecessary.

- In the supratidal zones of such beaches there is no natural mechanical action, and therefore the recommendations made for sandy or rocky areas are valid depending on the particle size of the materials.

4. TYPES OF BIOREMEDIES AND THEIR SUITABILITY FOR APPLICATION

If we consider the mechanisms that bioremediation seeks to enhance and the results achieved in natural areas, we can establish a number of criteria to determine the suitability and efficacy of a treatment, taking into account the characteristics of the area to be treated and the bioremediation formulae available.

A bioremedy must meet the following requirements:

4.1 Balancing excess carbon and promoting oxidation

The essential nutrients for this purpose are oxidized and reduced forms of nitrogen, phosphates and iron. Combined use of oxidized and reduced forms of nitrogen is to be recommended because it addresses the preferences of different microorganisms and it prevents sharp shifts of pH often caused by exclusive consumption of one or the other form. Iron is important, even in micronutrient concentrations, because it favours oxidation.

Petroleolysis can also occur in anaerobic conditions, but it has little relevance other than in substrates such as sediments affected by percolation or covered by the change in a beach's profile, and in buried pockets that can form as oil filters down from the surface. In any case anaerobic processes are always slower.

4.2 Supplying co-substrates and forms of "soft" carbon

Although apparently contradictory in a situation of carbon overload, there are numerous signs that the rate of biodegradation of fractions like the most stubborn polyaromatic hydrocarbons increases if more readily-assimilable carbon sources are supplied to act as co-substrates. In other words, "hard" carbon forms should be complemented by "soft" forms. While urea can serve as a simultaneous source of nitrogen and carbon, given the metabolic pathways followed by hydrocarbons it seems reasonable to suppose that the esters and fatty acids comprising the base of oil-based bioremedies will serve better as co-substrates.

4.3 Promoting bioaccessibility of fuel-oil and retention of microbiota

On sites such as rock formations, in view of the problems noted in section 3.7.1 it is essential that the bioremedy be formulated in such a way as to facilitate penetration of the oil layers or retain it on the polluted surfaces, so as to help keep the oil fluid and prevent it from setting (see section 3.4). It

1 The statements regarding treatment of supratidal rocks in the following sections are based on actual experience with the *Prestige* spill, which consisted of heavy fuel-oil (satured hydrocarbons: 30,5%; aromatic hydrocarbons: 40,1%; resins: 17,1%; asphaltenes: 12,3%). Because of the conditions in which the accident took place (strong tides and gales with high waves), the oil reached especially high supratidal levels, where it adhered fast to the rocks.

must also possess moderate dispersant ability to augment the area of contact with natural agents and promote hydrocarbon bioaccessibility. It must create surfaces capable of capturing and retaining microbiota (natural or from bioreinforcement if used) and must be reasonably resistant to rain lixiviation. In view of all these requirements, oil-based bioremedies are best suited to rocky areas. Water-based formulations are not suitable.

4.4 Permitting simple application protocols

A bioremedy should be usable without complicated protocols, which are of scant viability in practice. In their recommendations for use, the makers of bioreinforcements frequently state that in rocky areas affected by an oil spill the substrate needs to be slightly moistened two or three times a week. However, to do this will considerably increase the manpower required, when one of the supposed advantages of bioremediation is precisely that its requirements are simple.

5. FERTILIZER APPLICATIONS: DOSES AND FREQUENCY

The basic principles of bioremedial fertilization apply to whatever formulation is used, but the factors discussed in the foregoing section determine differences of method which need to be addressed, broadly distinguishing between fertilizing treatments that resemble agricultural treatments and those entailing more specific formulations.

5.1 Conventional agricultural fertilizers

5.1.1 Ratios between fundamental nutrients

When fertilizing-type bioremediation can be achieved with conventional agricultural products, a reasonable procedure to meet the requirements specified above is to estimate the amount of oil present (Q) per unit of surface to be treated (or volume in the case of biopiles and the like) and add the following weighted proportions of nitrogen, phosphorous and iron

$N \sim Q \times 0{,}10$
$P \sim Q \times 0{,}04$
$Fe \sim Q \times 0{,}00004$ (4×10^{-5})

which can conveniently be supplied (see section 3.1) by adding, per kg of oil estimated:

NH_4NO_3 244 g
$NH_4H_2PO_4$ 153 g

these are readily available commercially and in the quantities indicated supply:

N (nitric)	40,8 g
N (amonic)	59,1 g
P	40,3 g

There are likewise various commercial iron preparations (such as root and flowering inducers) commonly used in farming or gardening, which supply the element in chelated form along with various oligonutrients, some of them organic, which are also useful as microbial growth stimulants. Prices of preparations vary and are considerably higher in those containing hormone-carrying plant extracts, which are unnecessary for the purposes discussed here. And of course the dosage must be determined (following the Fe ~ $Qx4x10^{-5}$ formula cited above) on the basis of the iron content indicated in the formulation.

5.1.2 Concentration of solutions to be applied

Once the dosage of fertilizer is adjusted in the above terms to suit the amount of oil present, the concentration of the solution required to supply the right amounts of N, P and Fe must be estimated according to the porosity and absorbent capacity of the substrate. In poorly absorbent substrates, a reasonable dosage using a conventional pulverizer is normally around 0.5-1.0 litres per m^2. Larger volumes are needed to achieve acceptable penetration of soils or biopiles, so it will generally be necessary to work with more dilute solutions.

5.1.3 Possibility of supplementing with absorbent and adsorbent materials

To facilitate retention of bioremedial agents in substrates of low porosity or with a large proportion of sharply inclined surfaces, the solution should in principle be supplemented with 5-10% of some absorbent or adsorbent material. We would note, however, that according to the experience on which this procedure is based (see Introduction), the use of sepiolite, bentonite, clay or plant fragments for this purpose did not improve the results of water-based fertilizing either with or without various types of bioreinforcements.

5.1.4 Frequency of applications

This is naturally dependent on the rate at which the added nutrients disappear. It is recommended that the treatment be repeated when the ratio between the oil present and the nitrogen falls to levels between

1/5 and 1/10 of what was added initially.
With oil-based fertilizers it is possible to define criteria for visual monitoring, whereas with water-based fertilizers this kind of estimation is not possible and analytical methods must be used (see section 6: Methods for assessing the effectiveness of treatments). However, the rate of nitrogen depletion basically remains constant throughout the treatment, which means that reliable estimations can be made after one or two applications.

5.1.5 Possible utility of pH monitoring

Periodic measurement of the pH in substrates where reliable values can be derived (water, soils, biopiles and perhaps rocks) can help in adjusting fertilizer dosages more precisely. It is not an absolute criterion since it is affected by many factors, but shifts of pH towards acidity normally indicate preferential consumption of reduced (ammonic) forms of nitrogen, while a shift towards alkalinity indicates a preference for oxidized (nitric) forms. Since these consumption rates are —although not exclusively— dependent on the relative concentrations of the two forms, $N_{ox}/(N_{ox}+N_{red})$ and $N_{red}/(N_{ox}+N_{red})$, preferential consumption patterns generally reveal excessive supplies, so that a shift in pH can be used as a guide to readjust the above-cited proportions accordingly.
As we noted in sections 3.2 and 3.3, fertilizing with aqueous solutions, while effective on soils, are virtually useless on rocks. The added nutrients often vanish in less than a week, especially if it rains (even if absorbent materials are added), without having helped produce a significant increase over the control areas in the microbiota detected per unit of surface, using either conventional or molecular culture methods..

5.2 Fertilizing with oil-based products

The main difficulties entailed in treating rocky surfaces, already noted, are addressed to some extent by oil-based bioremedies, whose characteristics in this respect may be summarized in the following properties:

- They penetrate oil layers, delaying setting (see photo below).
- They are moderately dispersant, which enlarges the area exposed and promotes hydrocarbon bioaccessibility (see photo below).
- They facilitate retention of nutrients on treated surfaces.
- They promote capture of ambient microbiota or retention of bioreinforcements if used.
- They are relatively resistant to rain lixiviation and to high summer temperatures on oil-blackened surfaces.

- The supply additional carbon sources which can act as co-substrates.
- They generally require less repetitions than water-based fertilizers, since their penetration of the oil minimizes migration.

The main drawback to this alternative is the price, which is considerably higher than fertilizing with agricultural products.

5.2.1 Dosage

On the basis of the experience on which this procedure was built, the ratios between the surface area, the initial oil load and the total oil-based bioremedy dose applied in the course of the treatment can be determined as follows:

Initial oil load ~ 125 g/m^2 (1.25 mt/ha)
Total bioremedy dose

- per unit of surface area ~ 700 g/m^2 (7.0 mt/ha)
- per unit of oil present ~ 5.6 g/g (5.6 mt/mt)

At the same time, the rate of disappearance of the oil, as a limiting factor, is linked more closely to the capture and retention of ambient microbiota by the treated surfaces than to the doses of bioremedy in each application once a level of between 100 and 200 g/m^2 has been reached.

Granite tiles loaded with equal weights of oil after 20 days' exposure to the elements without (left) and with (right) an oil-based fertilizer. Note the moderate dispersant effect due to penetration of the bioremedy in the layer of oil.

The weighted proportions of the essential elements in these oil-based formulations may be similar to those in the formulations of conventional agricultural fertilizers.

5.2.2 Effect of increasing oil load

A load of 125 g/m^2 represents an oil layer approximately 0.125 mm thick, which means a surface "painted" with oil (like part of the tiles used for the procedures described in section 6). However, in rocky areas affected by an oil spill there are often discrete stains, so that the actual load is frequently smaller.
Nonetheless, increasing the dose per application or applying bioremedy to the substrate before the previous application has finished working does not substantially improve the efficacy of the treatment and is simply a waste of bioremedy. A greater oil load entails an increase in the time required to complete cleaning (after 5 months, equivalent treatments of oil from the Prestige removed ~82% with loads of 133 g/m^2 and ~40% with loads of 750 g/m^2). Also, when we say that bioremediation is a slow, finishing process, it should be understood that the duration cannot be reduced by overdosing with bioremedy beyond the levels specified in the foregoing section.

5.2.3 Frequency of applications and economic criteria

Generally speaking the load of bioremedy for each application ought, as we say, to be between 100 and 200 g/m^2. Higher loads tend to slide off inclined surfaces before they can penetrate the oil layer. Repeating smaller loads until cleaning is complete economizes on the product, but successive applications have to be more frequent, which raises the manpower demand.
The proper frequency of application —which is dependent on the rate of disappearance of the bioremedy the same as in water-based fertilization— can readily be estimated visually, by checking to see if the product on top of the substrate has lost its characteristic sheen. This is a good rule of thumb, although the bioremedy is often still detectable analytically in these conditions). The average time-lapse between applications is around 40 days, tending to be slightly shorter at summer temperatures and longer in winter (when efficiency is lower, not only because of low temperatures but also because of rain lixiviation despite the relative tenacity of the oil-based treatment).

5.2.4 Storage, equipment and mode of application

For efficient —and economical— application, oil-based bioremedies must be finely atomized over the substrate. Like all oil-based products, it is too viscous for the use of hand-operated atomizers, so that gasoline-powered devices like the one shown in Figure 5 are required. Viscosity increases sharply with falling temperature, which makes winter-time application difficult unless precautions are taken, namely storing the product at ~20-25ºC or delivering it at that temperature by heating with a coil.

When the liquid —which is an emulsion— is allowed to sit at any temperature, a whitish, urea-rich powder spontaneously settles and can eventually form quite thick agglomerations. For proper application, this sediment must be resuspended, which can be achieved by vigorous recirculation of the product, again at ~20-25ºC, using a pump. Finally, to maximize penetration of the bioremedy in the oil layer, attention must be paid to weather forecasts to ensure that it does not rain for two days after application of the product.

5.2.5 Use of oil-based bioremedies in biopiles

Oil-based bioremedies can also be used for treatment of earth substrates in biopiles. In such cases, however, they have to be diluted down to about 1/10 of the original concentration with water, which is mixed in by vigorous recirculation using a pump so that the oil base does not hinder aeration.

5.2.6 Monitoring the process

In certain conditions, the progress of bioremediation is apparent to the naked eye, but especially if it is desired to compare the results of

Correct way to operate and a gasoline-driven individual atomizer, suitable for application of oil-based bioremedies too viscous for manual atomizers.

different alternatives, the efficacy of the treatment should be monitored analytically by means of the procedures specified in section 7, with sampling more or less monthly.

In the case of vegetable soils, with or without biopiles, the characteristics of the substrate often make visual inspection difficult, but its homogeneity facilitates representative sampling. In this sampling it must be borne in mind that the material collected should ideally contain not less than 2 grams of oil, at least during the early stages of the treatment, for calculation of the various analytical indices that go to define the characteristics of the process and can be used as a basis for forecasts of progress. At later stages this procedure entails unnecessarily massive samples.

Representative sampling is difficult on rock substrates, and therefore the best solution is to prepare experimental surfaces in the same area for reference (see section 7). On the other hand, they generally make visual inspection easier: generally speaking, bioremedial action on these substrates is appreciable from the appearance of light-coloured haloes which advance slowly from the edges of the oil stains, and from progressive fragmentation of initially continuous coats in the areas where they are thinnest.

In any event it is recommended that the process be carried out by an experienced team of specialized scientists.

6. BIOREINFORCEMENTS AND THEIR LIMITATIONS

One of the most disputed aspects of bioremediation is the effectiveness of a bioreinforcement in ambient conditions, a technique which can in principle be performed by various different means. Experiments with several types of bacterial inocula on oil from the *Prestige* in rocky surroundings produced much poorer results than were achieved by applying the oil-based bioremedy without a bioreinforcement (see Annex 1). However, rock is a highly unsuitable substrate for any bioreinforcement to be effective, so this experience cannot be extended to other types of formation. This technique is discussed in Annex 3.

In fact there are numerous indications that the efficacy of bioreinforcement is crucially dependent on the area that is to be treated; it is very low in environments that are naturally poor in microbiota, such as rock formations, because the medium can only sustain a very small amount of additional biomass. As noted earlier, the efficacy of oil degradation in such areas is apparently dependent on the random capture of petroleolytic units from the surrounding environment, which are subject to mortality rates that prevent any significant increase in the active biomass: the model for the process is quite different form that of a microbial culture that grows as far as the substrate allows. Therefore, given that to maintain high concentrations of active biomass (which are constantly decreasing) would require repetitive application of the bioreinforcement, a costly option in preparatory work and equipment, the most efficient way would appear to be to promote the capture and retention of natural microbiota. Hence, in view of the adherent surfaces that they provide and the other characteristics already mentioned, oil-based fertilizers are the most suitable solution for areas of this kind.

7. METHODS FOR ASSESSING THE EFFECTIVENESS OF TREATMENTS

In view of the slow pace of bioremediation and the characteristics of the areas where they are usually applied, a simple visual inspection often prompts ambiguous and over-subjective estimations of progress. Such estimations can undoubtedly be rendered more accurate and objective by means of photography and image analysis techniques. However, more precise appraisals are often required, particularly if the intention is to compare various different means. In that case, it is necessary to resolve two interrelated problems —the heterogeneity of the area and the assessment criterion— linked to two types of situation where once again rock substrates are the most complicated to deal with.

7.1 The problem of spatial heterogeneity

Spatial heterogeneity produces large variations in the thickness and adherence of oil layers owing to variations in the texture of the substrate, hollows, ridges and the degree of exposure of different zones to environmental agents. Therefore, supposing that the initial condition of the system is established by sampling in a given area, there is very little assurance that the resulting samples come from areas in equivalent conditions.

7.1.1 Soils, biopiles

In basically flat ploughable soils, or in well-mixed biopiles, the substrate is a reasonably homogeneous particulate material, so that any set of samples can be accepted as essentially equivalent. Moreover, variability can be dealt with by means of experimental plans commonly used in agricultural work, such as the Latin square, which though costly due to the sample sizes required, allow reliable comparisons by means of statistical methods such as analysis of variance.

7.1.2 Rock formations

Generally speaking in rock formations there can be no assurance of sample equivalence, and therefore designs intended to control variability make little sense. The best option in such cases is to prepare more easily manageable experimental surfaces for comparison, for example in the form of panels of tiles; these are loaded with oil from the spill, placed in the area to be treated and subjected to the bioremediation procedures that it is desired to assess.

7.2 Image analysis

Image analysis is useful for objectivizing a visual inspection, which for its part is a direct, intuitive and in many ways highly suitable way of estimating progress in the recovery of an oil-polluted area. The chief limitation lies in the fact that this kind of analysis cannot gauge the thickness of the oil layer —indeed even less than the naked eye— so that the correlation of results with genuinely quantitative methods is only acceptable when the deposits in the target areas are thin, or once degradation of the oil has begun to create clear patches. There is a simple procedure for conducting image analysis, consisting of the following steps (the outcome is illustrated in figure 7 and the adjoining table, with an example using the two reference granite tiles).

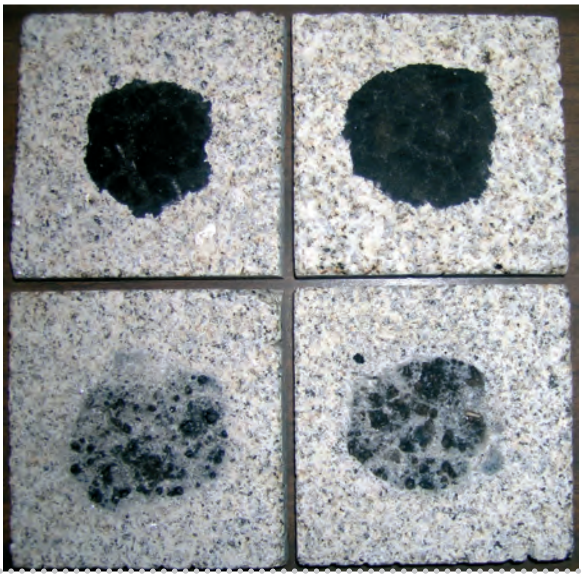
- Take digital photographs of the areas to be compared, with the same field (which should include a scale reference), the same resolution (high

Panels of reference granite tiles loaded with oil to suit different conditions. If the oil does not expand as a result of the dispersant effect, the tile can be loaded in two bands (top right) and sawed in half; the two parts are removed independently and the values they produce can be considered genuine replicates. Bottom right: two tiles untreated (above) and treated twice (below) with an oil-based bioremedy following the criteria described in section 4.2.3, after 4 months' exposure to the elements.

is best) and equivalent lighting (the most practical option for this is to use the flash in such a way as to avoid white noise points). In the case of small experimental surfaces (tiles or the like), it is recommended to take photographs that include treated and control units side by side, and to ensure that the same controls appear in the photographs of units subjected to different treatments if any.

- Use any digital image processing software to automatically adjust the colour levels in the photograph, then grey scale the image. It is not unusual for the two conversions to be superfluous, but they generally help to standardize the method, and at all events they do not interfere with the translation of the results.

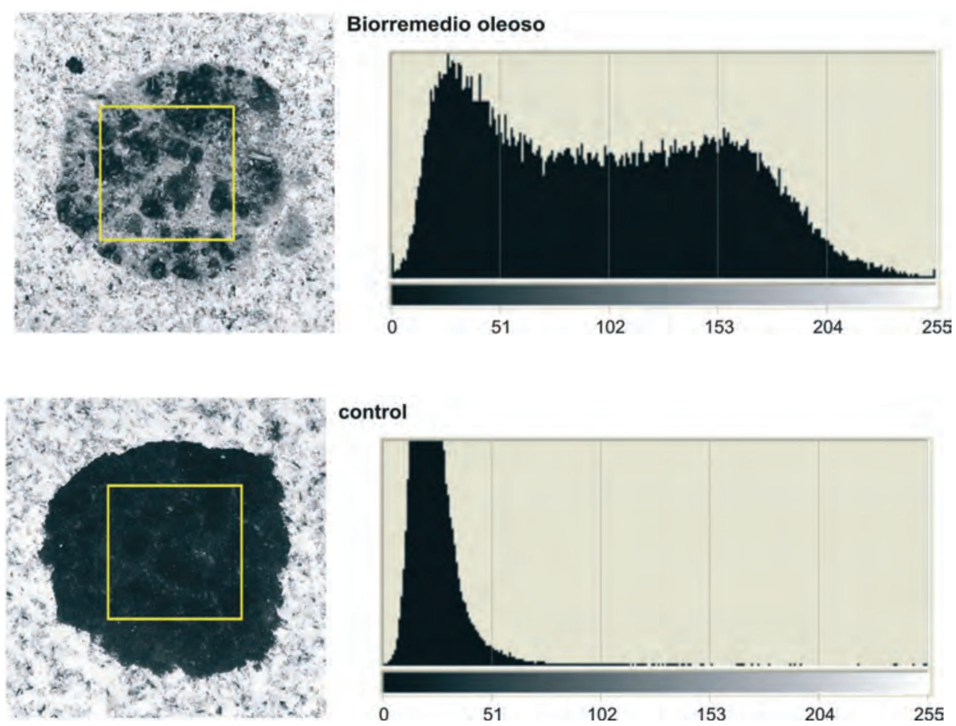
- Set a suitable pixel size for the area it is intended to select, apply the selection to the target area and get the histogram for it —that is, the spectrum whose x-axis plots the greyscale values from black (0) to white (255), and whose y-axis plots the number of pixels in the target area that coincide with a given point (degree of greyness) on the x-axis.



- Divide the x-axis into an arbitrary number of sectors and take the percentiles for each one. Figure 2, which compares two of the tiles shown in page 21, presents the histograms along with the corresponding tables of accumulative percentages in 5 equal intervals on the x-axis. However, other criteria for comparison can obviously also be defined from the histograms, in addition to several possible means of reducing each image to a single representative value, either of the oil remaining or the oil removed (a criterion of this kind is suggested at the foot of figure 2).

7.3 Quantifying remaining oil

The best assessment procedure is to compare the oil remaining in treated and untreated areas as extracted using a sufficiently vigorous solvent system such as dichloromethane:methanol (2:1). However, to obviate variability due to spatial hetereogeneity, various different indices have been proposed which



in principle are independent of that variability since they are based on the ratios between oil components which present significantly different rates of degradation.
The protocols for sample extraction, purification and fractionation, and the meaning and use of the two habitual indices and the criteria for deciding what should count as remaining contamination, are described in detail in Annex 4.

ANNEX I

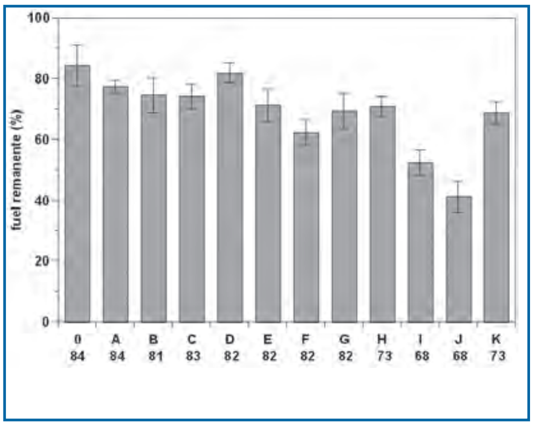
Immediate background to this handbook. Results of eleven bioremediation treatments on granite tiles loaded with oil from the *Prestige* and placed in a rocky supratidal location from March to October 2003.

Percentiles corresponding to the sectors of the x-axis indicated (cumulative percentages of píxels with the grey shades corresponding to these sectors).

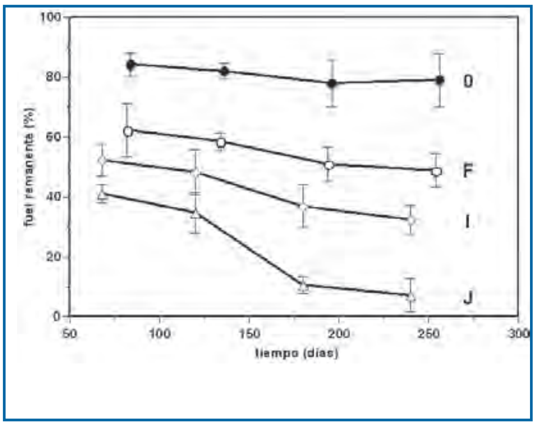
	0-51	0-102	0-153	0-204	0-255
Control	97,26	99,78	99,96	99,98	100
Treated	28,66	53,10	78,00	97,49	100

Figure 2: Use of comparative image analysis following the criterion described in section 6.2, as applied to two of the tiles shown in figure 6. Note that other criteria can be developed from the histograms in addition to the percentile table. For example: In the area demarcated by the yellow square, the percentile 99.9% is reached in the control element at x-value 114, while at the same x-value the percentile reached in the element treated with the bioremedy (oil-based) is 59,08%. This means that the treated tile contained 59,14% (59,08x100/99,9) of the oil on the control (note that the result obtained by extraction 59,96 %).

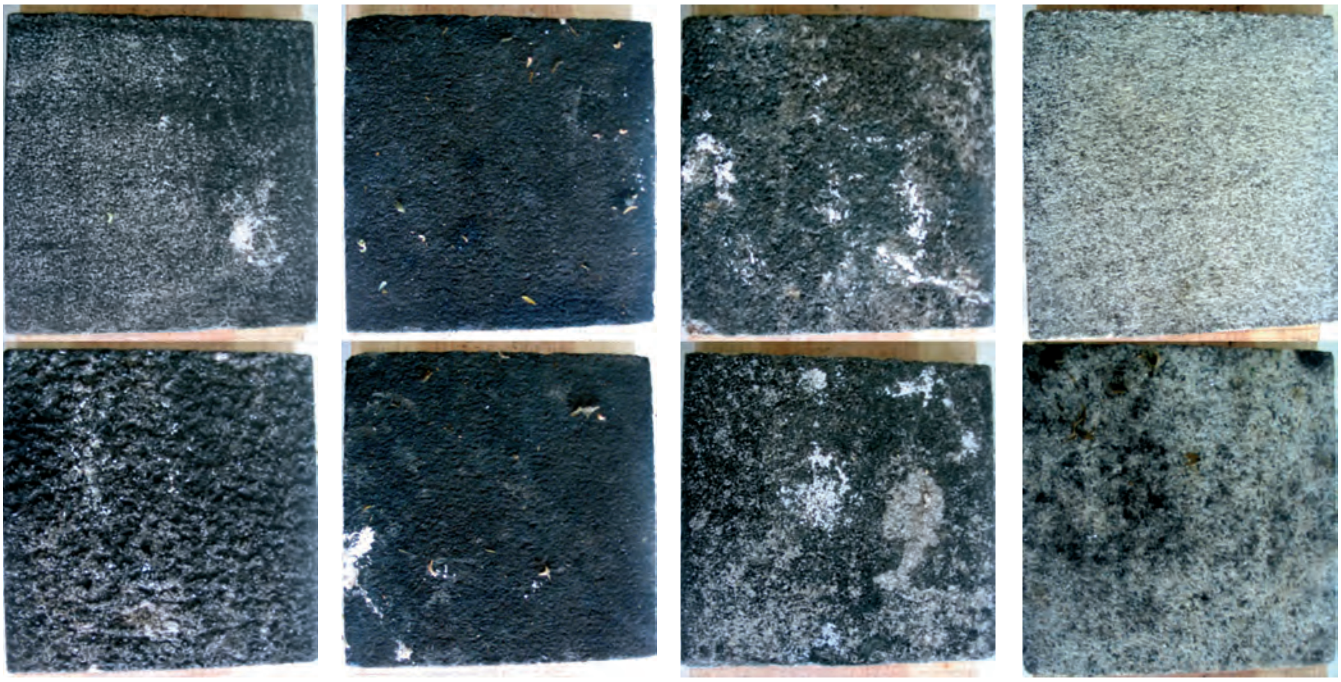
- A Simplest treatment: ammonium nitrate, ammonium phosphate and oligoelements according to criterion 4.1.1, with 5% sepiolite.
- B The same as A, plus a mixed bacterial culture (~1010 cells/L) isolated from an affected zone three weeks after the accident.
- C The same as B but substituting bentonite for sepiolite and adding 5% of plant fragments.
- D The same as C but in a formulation containing 10% natural surfactants.
- E The same as C, plus a commercial inoculum containing three wild strains of *Pseudomonas putida*.
- F The same as A but with the *P. putida* inoculum used in E.
- G The same as F, but with 5% sepiolite.
- H The same as A but without sepiolite, plus a commercial bacterial consortium and a micronutrient plant extract.
- I The same as H but substituting the commercial consortium with another similar to the one used in B.
- J A commercial oil-based formulation of urea, phosphoric ester and butoxyethoxyethanol in a water/oleic acid emulsion.
- K The same as A but without sepiolite, plus a commercial archaeobacterial inoculum on a clay medium, with urea, Cu, Mn, B and Mo.



C.3.1.
Effects of the different treatments (0: control) at the times indicated (days) below the x-axis.



C.3.2.
Subsequent evolution of the three treatments (0: control) selected after the period indicated in C.3.1.



C.3.3.
The three most effective treatments (0: control), at a slightly earlier stage (0, F: 210 days; I, J: 195 day) than at the final points in figure C.3.2.

ANNEX II

Criteria for a bioremediation balance sheet

Favourable factors

- 1. It breaks down hydrocarbons and does not merely disperse or move them.
- 2. It simply speeds up natural processes and therefore scarcely disturbs the ecosystem. In fact the slowness of the process is one of its drawbacks, so much so that it may be judged ineffective because there is little sign of its effects in the short term. Nevertheless, it prevents extraordinarily high persistence of oil on certain substrates with low microbiotic activity, like rocks.
- 3. If only fertilizing procedures are involved (fertilizers are the essential factor), only simple equipment is required for application and it is economical in terms of time and manpower.

Potential risks

- 1. Very slight or non-existent, with no empirical evidence. For instance:

  1.1 Eutrophication through the addition of fertilizers is only possible in waters that are enclosed or have very low exchange rates. In such cases, however, the effect would only be transitory and far less disturbing to the system than the presence of oil.

  1.2 bioreinforcement with cosmopolitan petroleolytic species is innocuous as long as the restrictions cited in the next annex are observed.

  1.3 The use of genetically modified species is unacceptable for reasons of biological prudence. However, the risk lies not so much in the expansion of petroleolytic enzyme-codifying plasmids (whose horizontal diffusion is similar to the spontaneous microbiotic response in an oil-polluted environment) as in the more problematic and hazardous issue of intervention in the operons (elements regulating and controlling combined expression of all the genes in a metabolic pathway or various related metabolic functions) which govern the transcription mechanism.

- 2. The dispersant effect of some bioremedies is very moderate (more so than that of the waves), beneficial and not at all comparable to the addition of massive doses of surfactants for rapid cleaning of a given area.

- 3. The intermediate metabolites that it produces are no different from the ones produced in natural petroleolysis.

Real drawbacks

- 1. The process is slow and can only be applied where levels of oil pollution are relatively low and mechanical methods are no longer effective.

- 2. Its efficacy is highly dependent on the type of substrate to be treated, and bioreinforcement is practically ineffective on substrates with low microbiotic activity in normal conditions.

- 3. Addition of bioreinforcements requires more equipment than is normally allowed. Oil-based bioremedies, which are essential on rocky substrates, are relatively costly.

ANNEX III

Problematics of bioreinforcement and microbial dynamics of bioremediation

- 1. Basic types of bioreinforcement

1.1 The most intuitive and immediate kind of bioreinforcement is the seeding of biomass produced from pure cultures of petroleolytic species. However, such an approach appears too schematic in that the degradation of oil requires sequences of reactions catalysed by enzymes that are not necessarily present in a single microbial species. In fact efficient petroleolysis is a collective property of the mixed populations that develop spontaneously in an oil-polluted environment in a matter of days. Rather than the work of a concrete genome, the process is the outcome of an 'ecogenome' —that is, a set of enzymatic activities distributed among several species in such a way that each one carries out a part of the overall process, but whose viability is dependent on capabilities that are not necessarily connected with hydrocarbons.
Also, the formation of such consortia is facilitated by bacterial sexuality, which permits horizontal diffusion of genes —hat is, the exchange of genetic material during couplings (unrelated to reproduction) between two or more individuals, sometimes of different species. Thus, in an environment subject to the selective pressure imposed by the presence of oil, it is highly probable that species capable of absorbing genetic information relating to petroleolysis will predominate after a number of generations (and there can be tens of bacterial generations in a single day).

1.2 A second approach, which strives to escape from the schematics of the first, consists in preparing multispecific inocula by repeated subculturing of a mixed bacterial population from a polluted area, in a medium whose sole carbon source is oil. The process eventually produces a stable consortium which after a period of fluctuation achieves stable proportions of species and petroleolytic capability. Although technically feasible, to generate such a system is a tedious task, requiring time and constant maintenance without resorting to cryostorage, for although this would facilitate the work, it could compromise the viability of some of the components of the consortium.

1.3 A third theoretical approach would be to work on the genome of species which are already good hydrocarbon degraders in a wild state and render them more efficient. In any case, for elementary considerations of prudence, the microbiota that may be used to produce bioenhancers have always been subject to the following set of restrictions to avoid biological risks:

- **They must not be genetically manipulated**
  to avoid horizontal diffusion of altered genomic material
- **They must not be photosynthetic**
  to prevent them from surviving in isolation from organic matter
- **They must be non-parasitic**
  to prevent them finding refuge in other biological entities
- **They must not produce spores or resistant propagules**
  to prevent the possibility of resurgence from states of latency

Leaving aside the possible biological risk, this third approach seeks to incorporate, in a single species, a package of enzymatic codes capable of catalysing an entire set of petroleolytic reactions. To start with we should say that possession of the enzymatic codes does not guarantee their actual expression; their actual expression does not guarantee effective catalysis (which may require energy that is unobtainable from the substrates present, or missing co-factors, such as surfactant metabolites to render the hydrocarbons bioaccessible); and lastly, the natural conditions in which the bioremediation process should take place may lack the metabolic couplings needed to sustain the viability of the bioreinforcement, may possess enough of them to negate such viability, may simply be hostile, or may be subject to excessively pronounced variations.

2. Dynamics of bioreinforcement

The approaches described above are of little relevance in some of the environments where bioremediation is most needed, such as the rocky areas addressed by this procedure, On a schematic level we may say that environments which sustain intense microbiotic activity in normal conditions respond well to fertilization and bioenhancement, without being overly affected by the difficulties entailed in the formation of complex consortia, since there are many cosmopolitan petroleolytic microorganisms that can thrive in the biochemical diversity of the medium. On the other hand, neither fertilization nor bioreinforcement achieve comparable results in environments habitually poor in microbiota. If we think of the differences in fertility between, say, a market garden and a beach, or a wood and a cliff, we can tell intuitively that the presence of oil and fertilizers cannot turn a strand or a rock formation into a substrate with comparable biological activity to that found in a vegetable soil or tilled land.
In considering the value of bioreinforcements, then, it will be well to bear in mind the following irregularities, cited from concrete actions in a variety of natural environments:

2.1 Petroleolysis generally follows a first-order kinetic (negative exponential).

2.2 Bioreinforcement does not alter the kinetic profile of petroleolysis, for even when it can be shown to improve the efficiency of fertilization, that improvement generally requires repeated, relatively massive additions and simply produces an increase in the rate of degradation (the velocity constant).

- 2.3 The biomass in the treated areas tends to remain stationary, and this, taken together with the two preceding points, implies that the dynamic of the bioremediation proces is that of a microbial culture with no nutritional limitations, where an initial biomass augments following an autocatalytic kinetics (logistical) and the carbon source disappears correlatively with this increase. Despite the apparent excess of nutrients, the bioreinforcement behaves more like a stationary biomass, in a process where the carbon source (the oil) will only allow a moderate specific growth rate, and the mortality balances the active biomass, preventing the onset of an exponential phase.

- 2.4 The ratio of total to cultivable microbiota and its seasonal variation are important factors for evaluating the suitability of bioreinforcement. In fact the microbiota from the reference tiles used in assays were examined using classical culture methods and molecular methods, showing that:

  - Following periods of 20-30 days, the cultivable microbiota per surface unit associated with the bioreinforcement additions declined to levels normal in untreated areas. After 40-60 days, the “personality” of the different bioenhancers identified by cluster analysis additionally disappeared, so that the microbiota in all areas, included untreated areas, resembled one another more than they did themselves two months earlier. This demonstrated not only that the bioreinforcements were not very stable, but also that there was significant seasonal variation.

  - The areas treated with oil-based fertilizer were no exception to this drift, but the values of the two habitual diversity indices (Shannon index and Simpson index) were generally higher than in any of the other treatments.

  - Also, bioremediation was —again generally speaking— more effective in zones subject to greater terrestrial influence (close to woodland or scrub) than in areas exposed to predominantly marine conditions.

  - In all cases there were fewer cultivable species than DNA types detected in the treated environments (although highly variable, the ratio frequently fell to nearly 1/10). This suggests that petroleolysis can be explained not only as a function of the cultivable species present but also as a function of other species which are not cultivable with existing culture techniques.

This hypothesis is borne out by the fact that the efficacy of an inoculum made with three species isolated from tiles treated with an oil-based bioremedy was not significantly enhanced in the laboratory.

ANNEX IV

Methods for assessing the effectiveness of treatments

1. Protocols for sample extraction, purification and fractionation

Figure 8 summarizes the preanalytical and analytical procedures applicable to ambient samples (or reference tiles like those in figure 6) contaminated with oil. Generally speaking, wherever possible the samples processed should contain a total of not less than 2 gr. of oil, so that the fractions are large enough to generate the analytical indices described below and to conduct gravimetric assays. The latter are the simplest and moreover correlate best with visual inspection or image analyses.
Chromatographic analyses (preferably GLC and ideally gas-mass spectrometry; HPLC may be used for the polyaromatic hydrocarbon fraction) require preliminary purification and fractionation by partition or adsorption chromatography (on silica-gel or aliminia columns), also depicted schematically in figure 3. These can furnish information on details of biodegradation and are useful as corroborative means, but they are not generally necessary to monitor bioremediation, which for the bulk of its duration involves very high concentrations of oil which are readily detectable by less sensitive methods (which are also frequently less susceptible to experimental error). However, they may be appropriate for detecting residual hydrocarbon concentrations in tissues of the surrounding biota.
When oil-based bioremedies are used, the remaining traces of their oils have to be eliminated from the deasphalted fraction. Saponification with methanolic KOH followed by partition between water and hexane separates the soaps into the water fraction; the extract in hexane must then be subjected to additional purification in a silica-gel column.
As noted in section 7, there are various indices which are not only useful for classifying the characteristics of the oil degradation process but are also largely unaffected by the variability inevitably associated with samples from certain environments. Following is an account of the meaning, use and limitations of two especially useful indices for monitoring of a bioremediation action.

2. Index B (alkane/isoalkane ratio)

This works essentially as follows: the boiling point of alkanes increases with molecular weight and decreases with ramifications, which hinder molecule packaging; ramified alkanes are degraded more slowly than linear alkanes, since the beta-oxidation enzymes are blocked at the nodes so that additional processes

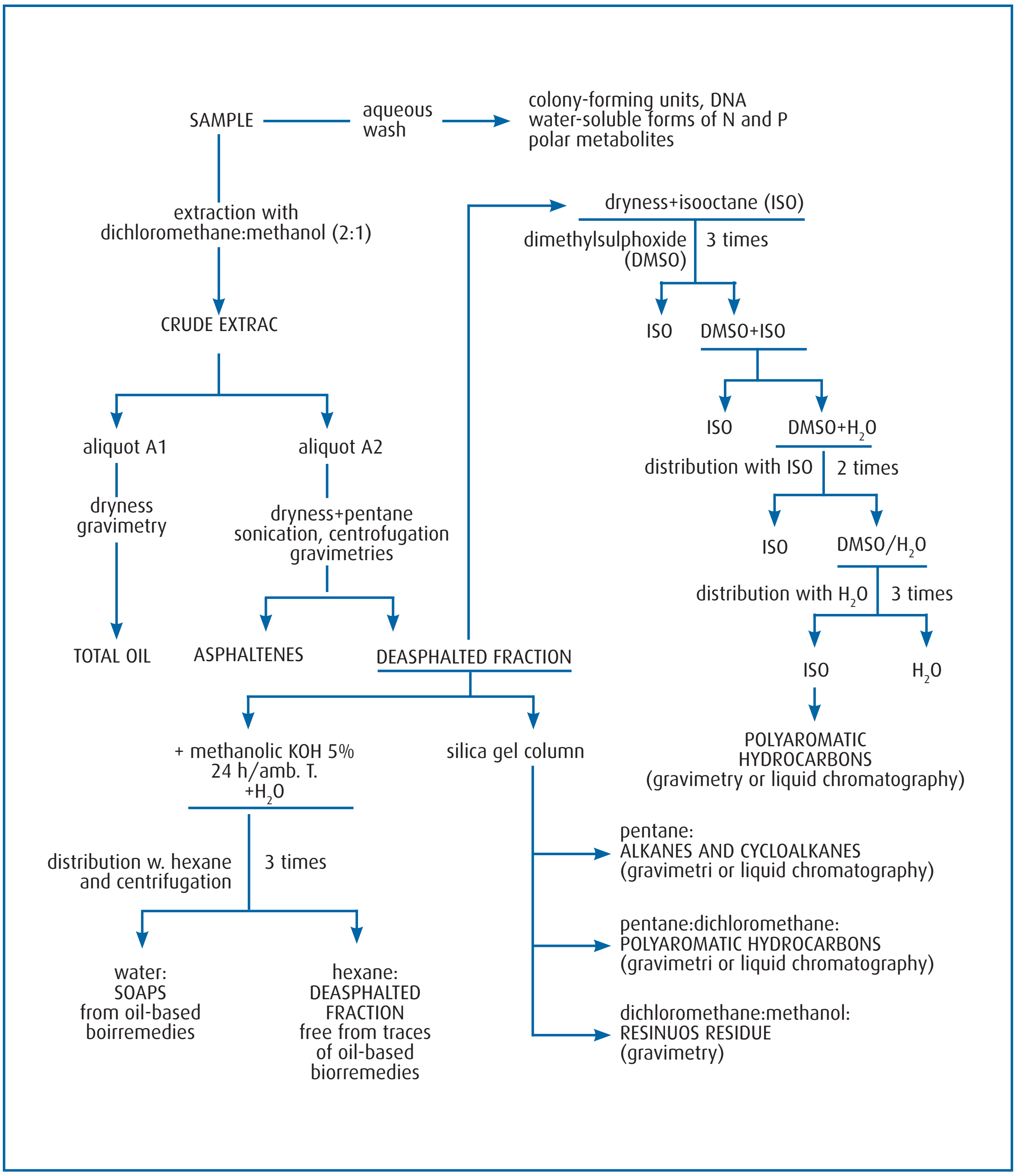


Figure 3: Treatment of reference tiles and fractionation of total oil extracts into the four principal component groups (alkanes plus cycloalkanes, aromatic hydrocarbons, resins and asphaltenes). Crude extracts were obtained by keeping the tiles in sealed glass containers with dichloromethane:methanol (2:1) for 24 hours at 20ºC, with gentle stirring. Redundant pathways (e.g. silica gel chromatography and ISO/DMSO/water distribution) were used only for corroboration. Also, saponification of the deasphalted fraction —which in many cases has to be supplemented with silica gel adsorption chromatography— is essential in the case of oil-based treatments to eliminate any traces of the formulation.

are required to eliminate the branches. Hence, although heavier, the ramified alkanes pristane and phytane have the same boiling points as the linear alkanes heptadecane and octadecane respectively. Thus, the relationship

$$B = \frac{\text{heptadecane} + \text{octadecane}}{\text{pristane} + \text{phytane}}$$

tends to remain constant in response to evaporative effects and to decline in response to biodegrading effects. Comparison of the values of B in a sample of the original oil and another sample that has been exposed to ambient factors thus furnishes a criterion to determine whether or not the state of degradation of the second sample is due to biological action.

The B index is undoubtedly useful and can be readily derived by gas-liquid chromatography of the alkane fractions of a heavy fuel oil, or even of crude extract of a Brent-type oil or a gas-oil. That said, it is of limited value since, as already noted, it varies in response to the action of biological mechanisms but is not strictly representative of the state of the system. Neither the linear nor the ramified elements cited are even remotely the most stable components of an oil, and therefore a value B=0 does not signify that the pollution has been eliminated.

- 3. The R index (deasphalted fraction / total oil ratio)

In laboratory work hopanes are commonly used as reference elements since they present a negligible rate of degradation, a property also shared by asphaltenes (defined for operational purposes as the fraction of the oil that is insoluble in pentane and soluble in aromatic hydrocarbons such as benzene or toluene). Thus, the relation

$$R = \frac{\text{total oil} - \text{asphaltenes}}{\text{total oil}} = \frac{\text{deasphalted fraction}}{\text{total oil}}$$

can acceptably reflect the progress of a bioremediation process, making it possible —with the additional condition of a first-order kinetics— to determine the mean rate of degradation of all the degradable components as a unit. The attached graph summarizes the way in which it should be applied and indicates the drawbacks, which again derive from the fact that not even asphaltenes remain unchanged throughout the treatment.

- 4. What should count as remaining contamination

Finally, there has occasionally been debate as to whether or not all the hydroxylated or carboxylated compounds produced by biological oxidation of hydrocarbons (aliphatic or aromatic) can properly be counted as remaining contamination. It seems clear, for instance, that alcohols or short-chain linear acids should not be classified as pollutants in the same category as oil. However, in the case of the result of hydroxylation, or even of dicarboxylic rupture on a benzene ring of a high-molecular-weight polyaromatic compound, it also seems clear that even if it is more bioaccessible it cannot be considered an end product of degradation.

In this connection, the schematic operational protocol shown in figure 8 —which is applicable as a preliminary in whatever assessment procedure may be decided on— also provides reasonable means to resolve this debate. Thus, if the polar groups introduced by oxidation constitute a major fraction of the molecule, this will be washed out in the initial aqueous wash all the more efficiently the more hydrophilic it is, and this will be reflected quantitatively in the organic extract. On the other hand, if these polar groups constitute a relatively insignificant fraction (as may be the case in high-molecular-weight HPAs) the derivate will pass —and properly so from a toxicological standpoint— into the organic extract of the oil.

Application and limitations of the index Rt

If we accept that of the total oil (T) only the deasphalted fraction (D) is degradable and that the asphaltenes retain their initial value (A0) for a long time, we can define a standardized index Rt (in which t is a temporary subindex) which provides an acceptable interpretation of the progress of degradation:

$$R_t = \frac{(T_t - A_0)/T_t}{(T_t - A_0)/T_0}100 = \frac{D_t/T_t}{D_0/T_0}100 \qquad [1]$$

If, as is usually the case, it is accepted that degradation on average follows a first-order kinetics with a specific rate r, we can write:

$$D_t = D_0 \exp(-rt) \qquad [2]$$

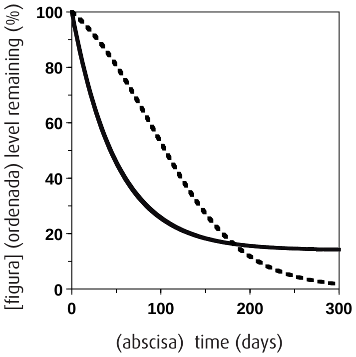
so that the standardized index Rt will obey the equation

$$R_t = \frac{D_t/T_t}{b_0}100 = \frac{100}{b_0}\frac{D_0 \exp(-rt)}{A_0 + D_0 \exp(-rt)} \;; \quad \text{where } b_0 = D_0/(D_0 + A_0) \qquad [3]$$

If we have a series of values of Rt, this expression can be used to estimate the rate of degradation r, and also the half life (t1/2) or time required to reach half of the initial value of the index (Rt=0=100). Thus, if we make Rt=50 in [3] and find t, we get

$$t_{1/2} = \frac{1}{r}\ln\left[\frac{D_0(2-b_0)}{A_0 b_0}\right] \qquad [4]$$

It is important to remember that although useful for smoothing experimental error, the index Rt is less discriminating than the remaining oil value, since Rt decreases less sharply with time than does the degradable fraction. The graph opposite illustrates the case with a simulation of the declines of Tt (unbroken line) and Rt (broken line) where A0=14 and D0=86 (approximate values for oil from the Prestige on the rocks), taking an arbitrary value of r=0.02 for the specific rate. How realistic this calculation is of course depends on the degradation of the deasphalted fraction (which includes components of different stabilities) fitting a first-order kinetics. Moreover, Rt will obviously lose validity if the asphaltenes vary as a direct or indirect consequence of the bioremediation process.



HANDBOOK 8

Recommendations for collecting and transporting oiled birds

1. INTRODUCTION

The purpose of this handbook is to provide a series of basic recommendations to guide decision-makers and to identify good practice for bird response units that go into action following an oil spill at sea. It is addressed to persons in positions of responsibility in management of the accident and to anyone who may be involved in officially coordinated and recognized operations within the framework of an overall response.

Yellow-legged gull with oil patches on its plumage.

Only seabirds are specifically dealt with as they are generally the worst affected in a spill. Other bird groups like waders and waterfowl (ducks and herons) may also be affected, if to a lesser extent. All the procedures described are also applicable to them.

The handbook falls into two clearly differentiated parts. The first seeks to guide decision making and the definition of strategies to prevent the oil from affecting birds and their habitats. The second deals with various aspects relating to coastal bird stranding.

After an oil spill there is a whole series of measures that can be taken to minimize its harmful effects on birds. However, it

is extremely important to distinguish clearly between on the one hand measures that a priori may be significant for conservation of affected species in terms of population, and on the other hand the rescue and rehabilitation work which is demanded by society but which in the light of results reported further below, in most cases do not significantly affect species preservation. In the wake of an accident the latter is necessary, but above all it is essential to ascertain the extent to which the population has been affected by the spill and to implement measures to facilitate the recovery of affected species, in view of our common responsibility to maintain them in a favourable conservation status.

It is also advisable to bear in mind the difference between bird recovery rate and release rate; the two terms are often confused and used indiscriminately, thus preventing accurate assessment of the achievements of a bird rescue and rehab operation. Recovery rates are difficult to calculate and refer to birds which manage dynamically to rejoin the population, while release rates refer exclusively to birds that are released after being treated in rehab centres, but whose subsequent fate is unknown.

Release rates are very variable and are affected by many factors, including oil type, spill location, degree of toxicity, speed of response, team experience, weather conditions, temperature and number of birds treated.

One common problem when assessing spill effects on seabird populations in particular, but also on other living organisms, is the absence of reliable time data series with ecologically significant parameters that could help to document and understand them. The setting up of programmes to monitor specific variables on a suitable temporal and geographical basis can help in understanding and evaluating not only spill effects but also other stocahastic incidents.

Furthermore, any response operation that is implemented must set clear-cut objectives which clearly establish the priority level of each one. Overall objectives in a bird response plan are to:

- a) Protect birds and their habitats from pollution.
- b) Minimize impact on birds and their habitats.
- c) Accurately quantify and assess damage in order to be able to prosecute, demand compensation and implement restoration measures.
- d) Minimize animal suffering (rehab or euthanasia).
- e) Minimize damage caused by cleanup operations.

2. HOW OIL SPILLS AFFECT SEABIRD POPULATIONS

It is worth recalling, albeit briefly, how a spill can affect seabird populations. An oil spill can produce direct and indirect effects. The direct effects are perhaps the most obvious and spectacular as they cause the death of birds through impregnation with oil or ingestion large amounts of it. Indirect effects generally go unnoticed and were not given all the attention that they deserve until the *Exxon Valdez* spill in Alaska in 1990. They are even more important than the first, since in the long term they may influence and limit species recovery (see for example Esler *et al.*, 2002; Golet *et al.*, 2002). The persistence of pollutants in the ecosystem may affect food availability

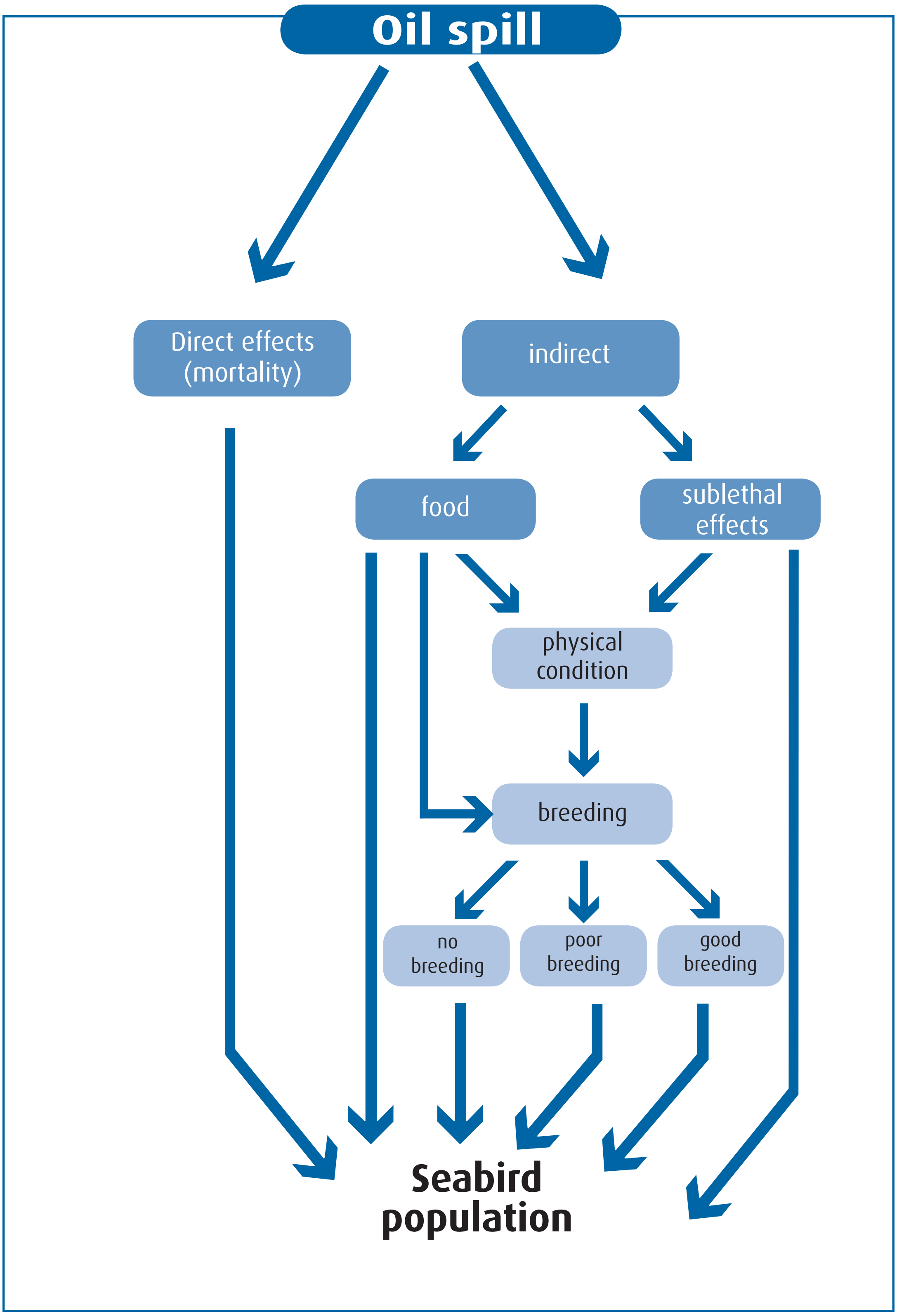


Figura 1. Oil spill effects on seabirds (modified from Arcea, 2003).

(see for example Velando *et al.*, 2005), leading to physiological problems (sublethal effects), which ultimately increase losses. Both factors also affect breeding, either directly or by negatively affecting the birds' physical condition. As a result, in the breeding season adult birds may not breed or breeding results will be poor (see Figure 1).

3. PART ONE

The time immediately following an accident at sea, whether hours or days, is vitally important as regards satisfactorily minimizing spill effects on birds and their habitats. They are critical and tense moments when it is very important for decisions to be well-thought out and sound. This first part contains a short guide to help in reaching the right decisions.

3.1 Guide to optimal strategies to prevent oil affecting birds and their habitats

When faced with an accident involving an oil spill in the marine environment, the persons in charge of anti-pollution work will ask themselves "What should we do?". To get through this initial phase, the following points respond to a number of possible doubts so as to help arrive at the best action strategies to protect birds and their habitats.

- 1. **Where did the spill occur?**
  We need to know the location of spill site as exactly as possible, i.e. if it is near or far from the coastline, in a port, a bay or an estuary.

- 2. **What is the scale of the accident?**
  Although there is not a direct correlation between the amount of oil and the scale of the damage (Burger, 1993), it will be useful to know, or failing that to forecast, the surface area of the sea or the length of the coastline that are going to be affected, as this will help to determine the possible extent of the impact on birds.

- 3. **What direction may the oil slicks drift in?**
  When the spill occurs far from the coast, it is very useful to have an estimation of the likely direction of drift, where the slicks may be expected to wash up and how long they will take to do so.

- 4. **What kind of geographical ambit is involved?**
  The possible effects of an oil spill at sea will be largely determined by the geographical ambit in which it has occurred, as each such ambit contains different seabird communities. This manual deals with three different ambits: the Peninsular Atlantic coasts, the Mediterranean coast and the Canary Islands, although other more precise ambits can be defined.

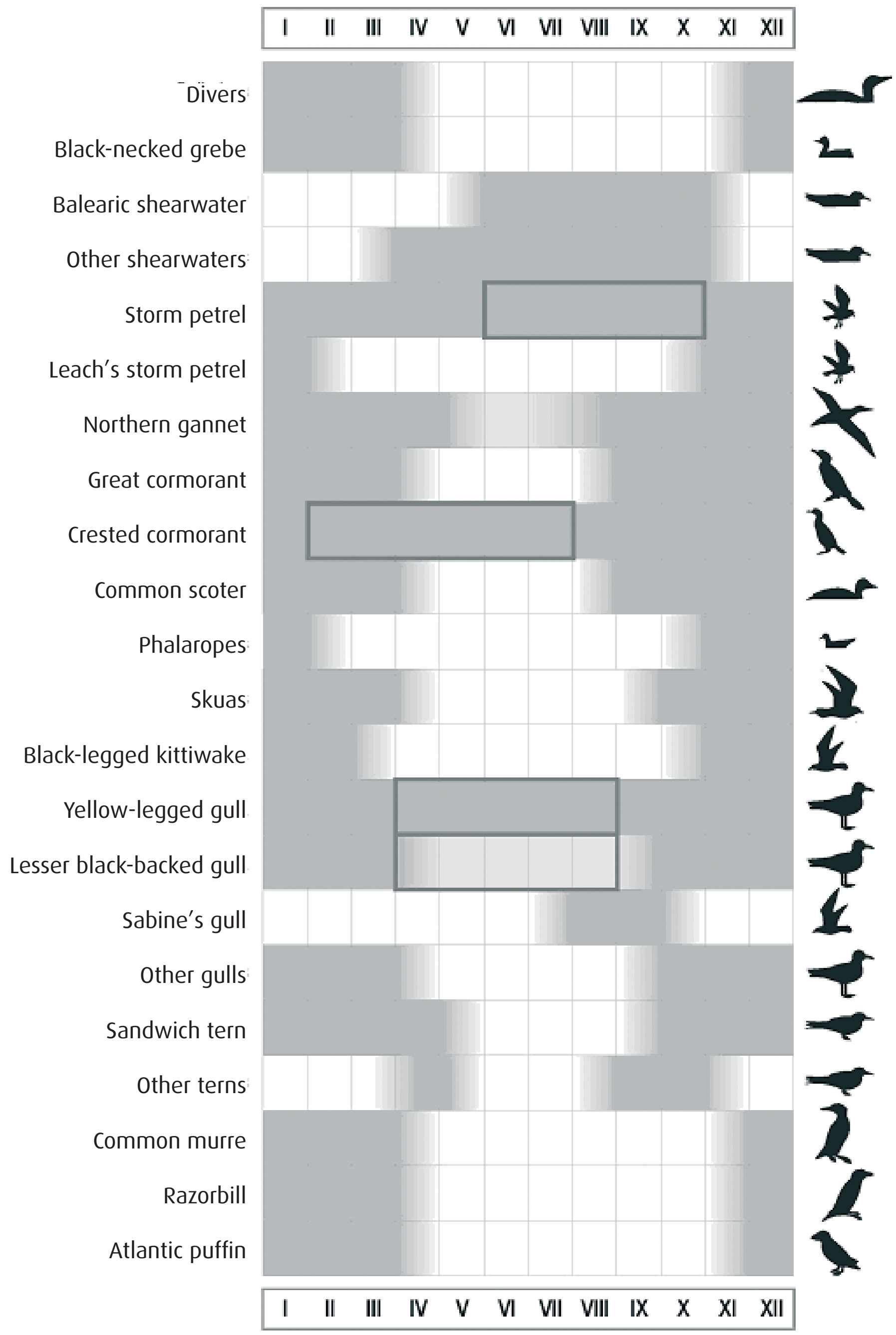


Figure 2.
Phenological chart of seabird species or groups of species on the Atlantic coasts of the Iberian Peninsula. The thickest lines roughly denote breeding seasons (Arcea, own).

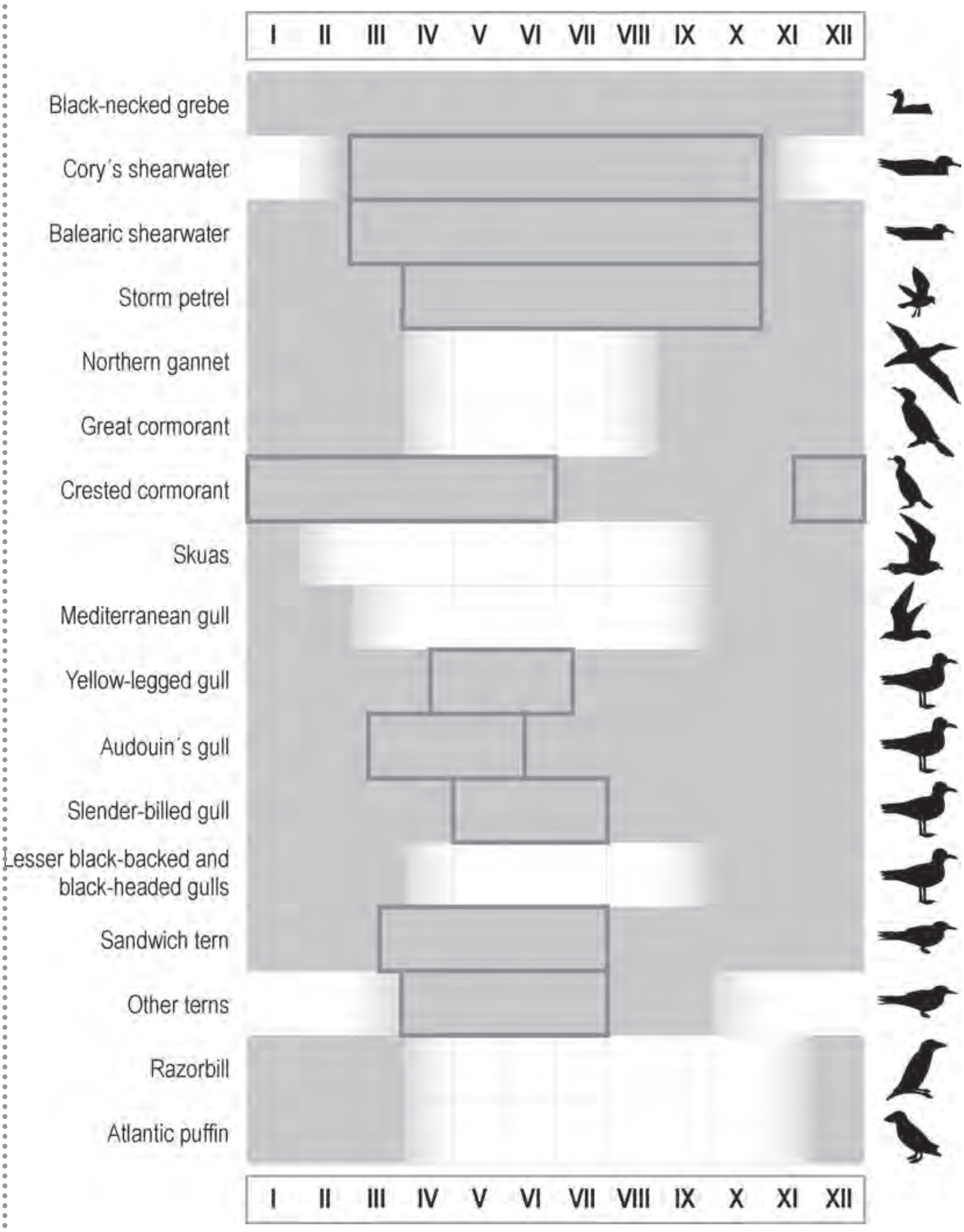


Figure 3. Phenological chart of seabird species or groups of species present on the Mediterranean coast. The thickest lines roughly denote breeding seasons (Arcea, own).

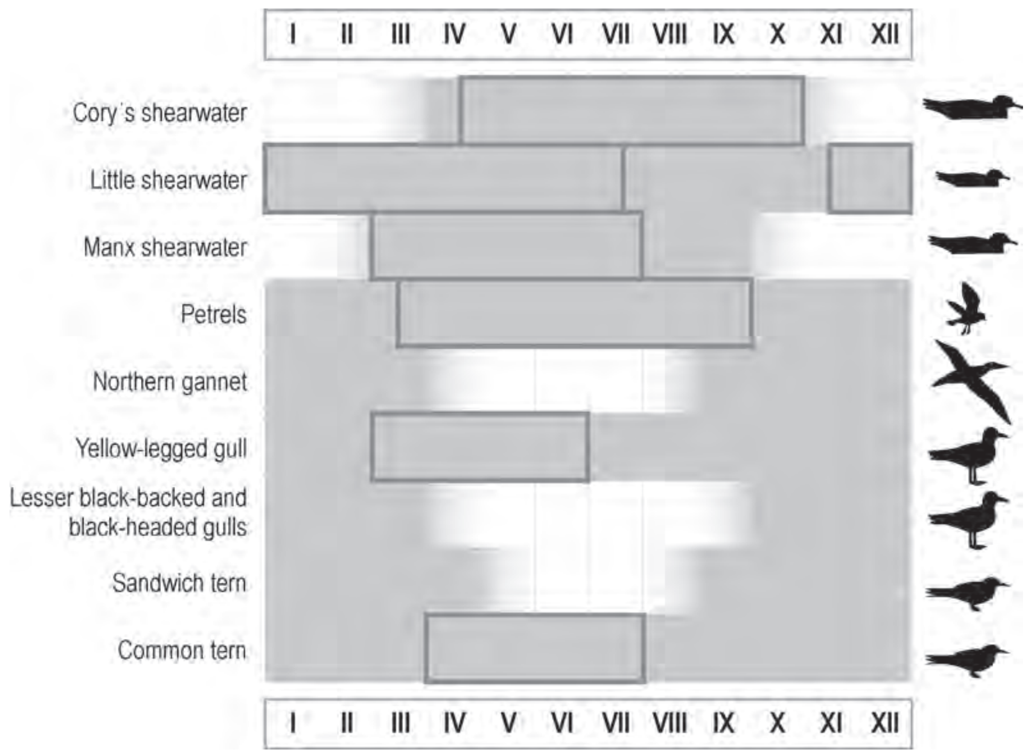


Figure 4. Phenological chart of seabird species or groups of species present in the Canary Islands. The thickest lines roughly denote breeding seasons (Arcea, own).

5. **What time of year did the spill occur?**
The date of the spill is important as the potential extent of the impact on birds will depend a great deal on the time of year. It may affect species which are in the process of breeding, which are at their wintering grounds or are simply moving from the latter to their breeding grounds.

6. **Which species are present?**
It is important to know beforehand the species present at least in the geographic areas of the spill. This information is shown approximately in Figures 2, 3 and 4, on a monthly scale, which also specify the breeding season of species which do so in Spanish latitudes since different communities of seabirds live in the different zones.

7. **What species are the most sensitive?**
We need to know which species are most liable to suffer significant harm and

channel the greatest intensity of prevention and anti-pollution efforts in that direction. Tables 1, 2 and 3 show the species potentially most sensitive to the effects of an oil spill. They have been arranged in descending order of sensitivity using an index calculated on the basis of the category assigned to each species in the Red Book of Birds of Spain (Madroño *et al.*, 2004), the size of the biogeographical population that converges on each area, their phenology, breeding characteristics (clutch size and age at first breeding) and dependence on the marine environment, partially modifying the methodology proposed by Williams *et al.* (1995).

8. **Where are the most sensitive species to be found?**

At least the major environments occupied by the most sensitive species present at the time of the accident must be identified, e.g. estuaries, large inlets or open sea. Annex I provides brief indications for each seabird group in Spain.

9. **What is the local distribution and numbers of the most sensitive species?**

It is very useful to have accurate data on birds' distribution and numbers; for instance, in an area where there are several inlets or estuaries, some may be more frequented than others or may host greater numbers, or birds may only gather in specific areas.

Oiled crested cormorant.

SPECIES	OSI
Balearic shearwater *(Puffinus mauretanicus)*	29
Crested cormorant *(Phalacrocorax aristotelis)*	27
Great northern diver *(Gavia immer)*	26
Little shearwater *(Puffinus assimilis)*	25
Little tern *(Sterna albifrons)*	24
Great skua *(Catharacta skua)*	24
Sooty shearwater *(Puffinus griseus)*	24
Sandwich tern *(Sterna sandvicensis)*	23
Red phalarope *(Phalaropus fulicarius)*	23
Great black-backed gull *(Larus marinus)*	23
Cory's shearwater *(Calonectris diomedea)*	23
Manx shearwater *(Puffinus puffinus)*	23
Red-throated diver *(Gavia stellata)*	22
Whiskered tern *(Chlidonias hybridus)*	22
Leach's storm-petrel *(Oceanodroma leucorhoa)*	22
Storm petrel *(Hydrobates pelagicus)*	22
Northern gannet *(Morus bassanus)*	21
Black tern *(Chlidonias niger)*	21
Little gull *(Larus minutus)*	21
Slender-billed gull *(Larus genei)*	21
Parasitic skua *(Stercorarius parasiticus)*	21
Black-throated diver *(Gavia arctica)*	20
Common tern *(Sterna hirundo)*	20
Yellow-legged gull *(Larus michahellis)*	20
Lesser black-backed *(Larus fuscus)*	20
Razorbill *(Alca torda)*	19
Mediterranean gull *(Larus melanocephalus)*	19
Pomarine skua *(Stercorarius pomarinus)*	19
Gull-billed tern *(Gelochelidon nilotica)*	19
Black-necked grebe *(Podiceps nigricollis)*	18
Common murre *(Uria algae)*	17
Atlantic puffin *(Fratercula arctica)*	17
Northern fulmar *(Fulmarus glacialis)*	17
Little auk *(Alle alle)*	17
Black-legged kittiwake *(Rissa tridactyla)*	16
Greater shearwater *(Puffinus gravis)*	16
Great cormorant *(Phalacrocorax carbo)*	15
Arctic tern *(Sterna paradisaea)*	15
Sabine's gull *(Larus sabini)*	15
Common scoter *(Melanitta nigra)*	15
Wilson's storm-petrel *(Oceanites oceanicus)*	14
Black-headed gull *(Larus ridibundus)*	13

Table 1. Oil sensitivity index (OSI) values for seabirds on Spain's Peninsular Atlantic coast (Arcea, own).

SPECIES	OSI
Balearic shearwater *(Puffinus mauretanicus)*	30
Audouin's gull *(Larus audouinii)*	27
Great northern diver *(Gavia immer)*	26
Crested cormorant *(Phalacrocorax aristotelis)*	26
Yelkouan shearwater *(Puffinus yelkouan)*	26
Slender-billed gull *(Larus genei)*	25
Cory's shearwater *(Calonectris diomedea)*	25
Sandwich tern *(Sterna sandvicensis)*	24
Little tern *(Sterna albifrons)*	24
Great skua *(Catharacta skua)*	24
Whiskered tern *(Chlidonias hybridus)*	23
Little gull *(Larus minutus)*	23
Red-throated diver *(Gavia stellata)*	22
Common tern *(Sterna hirundo)*	22
Storm petrel *(Hydrobates pelagicus)*	22
Northern gannet *(Morus bassanus)*	21
Black tern *(Chlidonias niger)*	21
Parasitic skua *(Stercorarius parasiticus)*	21
Black-throated diver *(Gavia arctica)*	20
Mediterranean gull *(Larus melanocephalus)*	20
Yellow-legged gull *(Larus michahellis)*	20
Leach's storm-petrel *(Oceanodroma leucorhoa)*	20
Razorbill *(Alca torda)*	19
Great black-backed gull *(Larus marinus)*	19
Lesser black-backed *(Larus fuscus)*	19
Pomarine skua *(Stercorarius pomarinus)*	19
Gull-billed tern *(Gelochelidon nilotica)*	19
Black-necked grebe *(Podiceps nigricollis)*	18
Common murre *(Uria aalge)*	17
Atlantic puffin *(Fratercula arctica)*	17
Black-legged kittiwake *(Rissa tridactyla)*	16
Common scoter *(Melanitta nigra)*	16
Great cormorant *(Phalacrocorax carbo)*	15
Northern fulmar *(Fulmarus glacialis)*	14
Black-headed gull *(Larus ridibundus)*	14

Table 2. Oil sensitivity index (OSI) values for seabirds of the Mediterranean coast (Arcea, own).

SPECIES	OSI
Band-rumped storm-petrel *(Oceanodroma castro)*	29
Little shearwater *(Puffinus assimilis)*	29
Bulwer's petrel *(Bulweria bulwerii)*	29
White-faced storm petrel *(Pelagodroma marina)*	28
Balearic shearwater *(Puffinus mauretanicus)*	28
Manx shearwater *(Puffinus puffinus)*	25
Cory's shearwater *(Calonectris diomedea)*	24
Sooty shearwater *(Puffinus griseus)*	24
Sandwich tern *(Sterna sandvicensis)*	23
Common tern *(Sterna hirundo)*	22
Red phalarope *(Phalaropus fulicarius)*	22
Leach's storm-petrel *(Oceanodroma leucorhoa)*	22
Storm petrel *(Hydrobates pelagicus)*	22
Mediterranean gull *(Larus melanocephalus)*	21
Great skua *(Catharacta skua)*	21
Parasitic skua *(Stercorarius parasiticus)*	21
Pomarine skua *(Stercorarius pomarinus)*	21
Northern gannet *(Morus bassanus)*	20
Yellow-legged gull *(Larus michahellis)*	20
Black tern *(Chlidonias niger)*	19
Great black-billed gull *(Larus marinus)*	19
Lesser black-backed *(Larus fuscus)*	19
Gull-billed tern *(Gelochelidon nilotica)*	19
Atlantic puffin *(Fratercula arctica)*	16
Black-legged kittiwake *(Rissa tridactyla)*	16
Greater shearwater *(Puffinus gravis)*	16
Black-headed gull *(Larus ridibundus)*	14
Wilson's storm-petrel *(Oceanites oceanicus)*	14
Black-necked grebe *(Podiceps nigricollis)*	14
Sabine's gull *(Larus sabini)*	13

Table 3. Oil Sensitivity Index (OSI) values for seabirds of the Canary Islands (Arcea, own).

- 10. **What are the critical points according to the bio-ecology of the most sensitive species?**
  There are specific places or areas which in terms of the biology and ecology of each species are critical in the event of an oil spill, since that is where large numbers congregate. Roosting, feeding, breeding and other areas must be pinpointed.
  Coastal sensitivity maps set out in detail the information needed to be able to answer the last three questions and are essential if an oil spill is to be combated as efficiently as possible. Sensitivity indices for each species are

essential components of these maps.
There is a wide range of possible scales for sensitivity; Figure 5 provides a hypothetical example.

- 11. **What can be done to protect critical sites?**
Once the critical sites have been identified, it must be determined how best to protect them. There are two broad types of strategy, which are never mutually exclusive: a) physically protect the areas on which the species depend to prevent them –and with them the species– from the effects of oil slicks, or b) take direct action on the birds, frightening them away from polluted areas, catching them for transfer to unoiled areas or keeping them in captivity until they can be released without risk of oiling (see Annex II).

- 12. **How effective will the methods chosen to protect critical sites be?**
It is very important to consider potential problems arising from conservation measures, and to be aware of their effectiveness and their real limitations, but no efforts should be spared when an action is deemed to be useful.

- 13. **What amount and type of material is needed to protect critical sites?**
Contact people with technical knowledge and proven experience in implementing the chosen measures. If you know exactly what you want to protect and how to do so, you will be able to estimate the amount of material needed.

Oiled puffin in a box, ready to be transported.

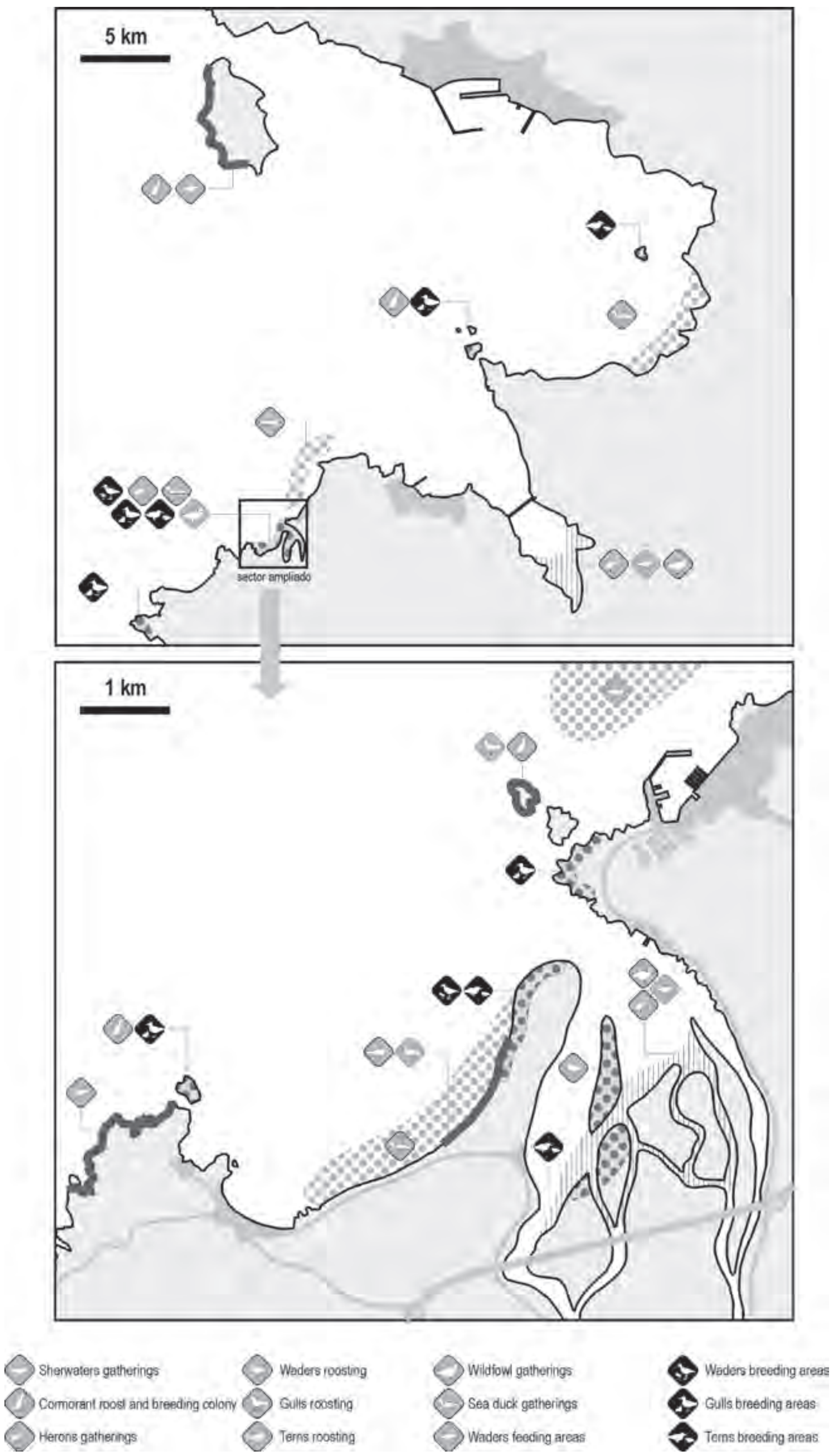


Figure 5. Example of a map of coastal sensitivity to an oil spill (Arcea, own).

- 14. **What material is available?**
  You need to know precisely how much material is available in order to judge whether it will be enough to meet the objectives that have been set. If there is not enough, take steps to obtain more. At worst it may be necessary to rethink the scope of the objectives.

- 15. **What human resources are needed?**
  Each protection method will involve mobilizing varying numbers of personnel, in most cases qualified; the number will depend on the scale and geographical scope of the work to be done. If you know what you want to protect and how, you can estimate the personnel requirement.

- 16. **What human resources are available?**
  You need to know precisely how many people are available, and if there are not enough to achieve the objectives, take steps to mobilize more. If the worst comes to the worst, you will have to rethink the scope of the objectives.

4. PART TWO

In any oil spill at sea, large and variable numbers of different bird species will inevitably be affected despite all prevention efforts. Of those birds, only some will reach the coastline, whether alive or dead. There are many measures to deal with them. The sections below cover various aspects related with this work and include a series of recommendations for achieving the best results.
They deal with: 1) search strategy along the coast, 2) data collection in the field, 3) strategies for catching wild birds, 4) techniques for catching and handling live birds, 5) first aid for live birds, 6) live bird transfer to rehab centres and 7) release of rehabilitated birds.

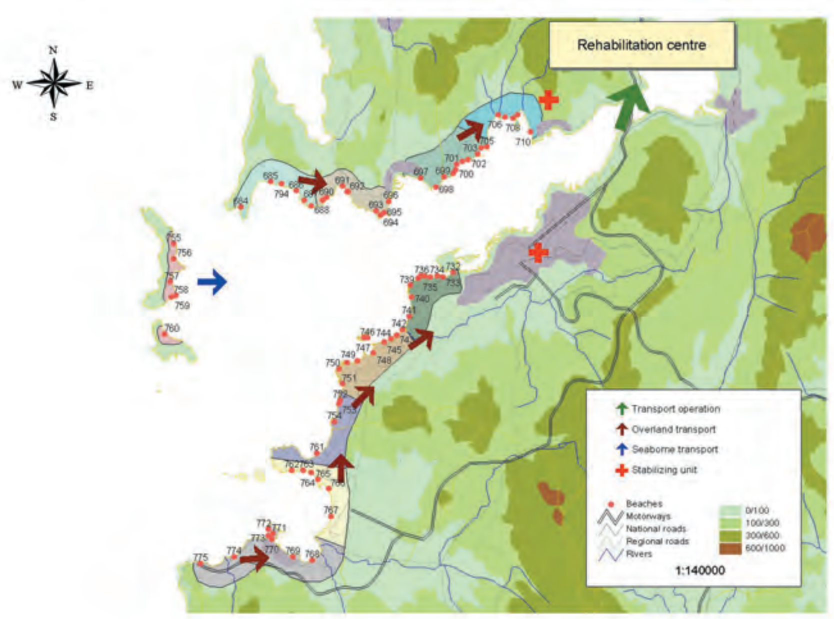


Figure 6. Hypothetical search strategy on a stretch of coast (Arcea, own).

4.1 Search strategy

Monitoring of effort is essential in organizing any bird searches along the coast. If such monitoring cannot be guaranteed for the entire oiled area, it must be done

for a number of representative sections. It is always preferable to ensure good monitoring in some sectors than to try to cover them all and in the end be unable to gauge the surveying effort accurately. By knowing the survey effort, the total number of beached birds can be estimated.
The sampling unit is the beach, which will be used as reference to identify the geographical origin of each bird picked up alive or dead. There may also be units of accessible rocky coast comparable to beaches, and others that are inaccessible to people. It is recommended that the geographic action areas be divided up into small sections (compartmentalizing the coastline), grouping small numbers of beaches in the same area which can be inspected by a two-person team. These sections must be demarcated with accessibility in mind. The entire series will be the basis for organizing searches and for efficient distribution of human resources. They must be established beforehand and uploaded to a Geographic Information System for easy handling and management. These sections will be activated depending on the extent of the spill and will be the basis for varying the search strategies. There must be specific differentiated teams for catching live birds or collecting dead ones.
There must be a hierarchical structure for collecting birds from the base sections to sites common to several close sections of coast, from where they are taken to stabilization and rehabilitation centres (see Figure 6). It is recommended that these sites be identified beforehand in order to organize daily work, arrange equipment distribution, make recommendations, resolve any queries or channel spontaneous volunteers. They should be made public.

Oiled cormorant.

Figure 7.
Example
of a label.

Figure 8. Model field card

COASTAL INSPECTION CARD

Surveyor's name:

BIRDS ALIVE/DEAD
(delete as appropriate)

Section: 1

Beaches (codes): 762 Portocelo, 763 Das Ribas Brancas, 764 Area Fofa, 765 A Madorra, 766 Panxón, 767 América

Date	Survey start time	Beach (see codes)	Species	No. bird	Oiled	Notes
				yes/no		
01/01/06	10:30	762	none			
01/01/06	10:45	763	none			
01/01/06	11:30	764	none			
01/01/06	12:00	765	murre	01	yes	
01/01/06	12:00	765	razorbill	02	yes	
01/01/06	12:45	766	none			
01/01/06	13:00	767	murre	03	yes	
01/01/06	13:00	767	murre	04	yes	Ringed ZA08
01/01/06	13:00	767	razorbill	05	yes	
01/01/06	13:00	767	gannet	06	no	
01/01/06	15:00	767	murre	07	no	

4.2 Field data collection

There must be a protocol for data collection in the field that is common for live and dead birds. Live birds must be placed individually in well-ventilated boxes and dead ones individually in bags. The following information must be marked on the outside of the box or bag in indelible ink: a) date (day, month, year), b) a beach identification code (which will be transferred to the survey team at the coordination point and which will have been allocated beforehand when the coastline was divided up), c) time the beach survey started and d) the number of the survey in question (Figure 7). This information will also be recorded on the individualized field card for each section, where the species should be noted. This card is handed over at the nearest coordination point at the end of each day (see Figure 8).

Basic material needed for labelling and transfer of birds:

- Hard-wearing bags of various sizes.
- Different sizes of hard-wearing containers with lids and holes 2.5 cm.w diameter in the upper and lower parts on at least two sides.
- Indelible ink markers.
- Hard-wearing labels.

4.3 Live bird capture strategies

The overall objective of a plan to collect live birds is to locate and catch the largest number in the best conditions and shortest possible time, to ensure the best chances of recovery. When human resources and/or financial resources are limited, the priority should be to catch the most sensitive species, and of these the least oiled birds –and hence the ones with the best chances of recovery.
There should be overall plans for reconnaissance and capture, but also specific ones for specific highly complex areas. In such cases particular sites and capture methods should be specified on the basis of the ecology and behaviour of the different species that may be affected. There must be specific live bird capture teams, separate from those collecting dead birds.
The most attention should be devoted to the coastline, but it may sometimes be necessary to catch them in the water. This option is secondary in the opinion of Berg (2003), who considers that since oiled birds are stressed, chasing them from boats raises their energy consumption and stress levels, so they should be left to reach the coast by themselves. IPIECA (2004), on the other hand, views capture at sea as a way of preventing birds from becoming so weak as

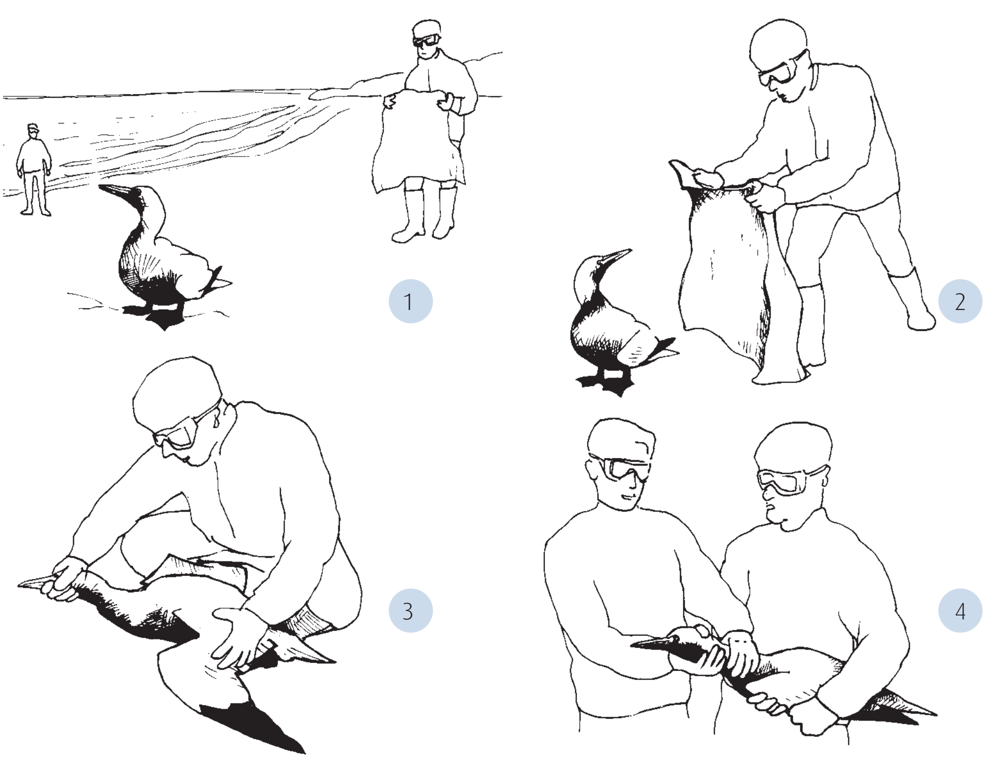


Figure 9. Basic steps in catching and handling a large oiled bird.

to severely threaten their chances of recovery. If birds are to be caught from the water, knowledge of their diving habits may improve the success rate. Berg (2003) estimates that if a bird is not caught after 3 or 4 attempts, it should be decided whether to carry on trying, at the risk of its drowning, or wait for it to reach the coast.

4.4 Live bird capture and handling techniques

Catching and handling live birds requires a certain amount of practice and previous experience and so should only be attempted by trained and authorized personnel. Stress should be reduced to a minimum, ensuring that the bird does not hurt itself or the handler. Difficulty depends on the size of the bird, how oiled it is and how much energy it has left; oil usually prevents birds from flying but they can still run, beat their wings, swim and even dive. Special care is needed with large birds with long necks and sharp or hooked beaks such as divers, gannets and cormorants.
Every capture team must consist of at least two people working together, although with large numbers of birds several people will be needed and capture strategies will have to be devised. In such cases it is useful to drive the birds towards a point where they can easily be caught.
Before initiating any capture measures, it is essential to take the necessary safety precautions, consisting at least of the use of gloves and goggles to prevent accidents to the eyes and face. White *et al.* (1998) note that early morning searches at low tide are usually the most successful as oiled birds strands on the shore at the end of the day, and there is more room for teams to manoeuvre.

Figure 10. Handling a petrel.

Figure 11. Handling a common murre.

1. Mechanical means should never be used to prevent a bird from opening its beak.

Figure 10

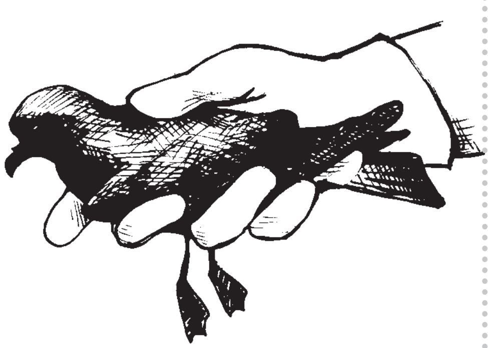


Figure 11

By way of general recommendations, catching must be done decisively and silently, ensuring as far as possible that birds do not run long distances and become stressed. They must be approached from behind or the side; towels, sheets or the like are useful to cover them. One member of the team must get between the bird and the sea while the other catches it. Its head must first be gently and firmly restrained by pressing the base of the beak and immediately afterwards the body, keeping the wings folded and preventing it from gaining purchase with its legs on a firm surface; the second team member will be needed for this. The bird must always be held at or below waist height (Figure 9).

The most appropriate handling techniques will depend on species and size. Small species such as petrels or phalaropes may be handled with one hand (Figure 10); medium-sized ones, such as ducks or alcids, should be held with both hands, ensuring that it can breathe properly (Figure 11). For large birds, such as gannets or cormorants, two people are needed to control the head and the body respectively. Aggressive species require additional measures to control the head and feet and should only be handled by personnel with experience in the field. Fowler (1995) includes a more comprehensive description of handling techniques.

It is not appropriate to use mechanical methods such as rubber bands, etc. to prevent a bird from opening its beak (see photo).

The bird is then put into a cardboard box with holes, and the data specified in the field data collection section are noted. Occasionally snares, hand-nets, different kinds of nets (e.g. cannon or Japanese nets) and barriers, or even other methods, may be used; the specific need should be analysed in each case. Many of these techniques require the participation of authorized personnel who are

Handling a lesser black-backed gull.

experienced in their use. In a 1996 publication *Bird trapping and bird banding*, H. Bub describes many capture techniques that may be of interest.
Handling wildlife in general entails a number of risks which must be taken into account. These are set out in Annex III.

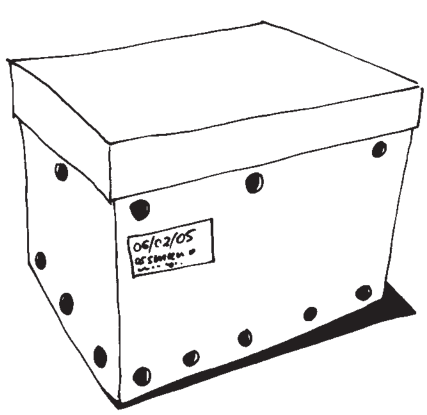
4.5 First aid for live birds

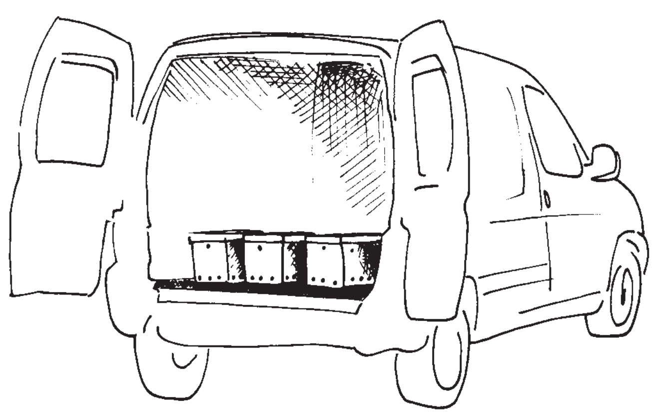
First aid for live birds must be administered by vets or specialized personnel at stabilization centres, where the birds should be taken as quickly as possible. Berg (2003) recommends carrying out stabilization treatments in the field if it is going to take 2-3 hours to get them to a centre. The author sets out the following steps:

- 1. Clean the mouth, nostrils and eyes. Oil and other residue may be affecting breathing.
- 2. Regulate temperature. Oiled birds lose the ability to regulate their body temperature. Take the bird's temperature so that it can be warmed up or cooled down accordingly. Once it is normal, it should be closely watched to detect any signs of its becoming chilled or hot (warm feet, breathing with the mouth open, etc.).
- 3. Treatment for dehydration. Oiled birds are usually dehydrated, and so fluids (electrolytic solutions) need to be administered regularly from the moment the body temperature is stabilized. If the bird's admission is going to be delayed, a stomach protector can be administered to reduce the effects of ingesting oil.
- 4. Minimize stress. Keep birds in a safe, quiet and warm place free from disturbance and noise.

Figure 12. A transport container for oiled seabirds.

Figure 13. Containers arranged in a transport vehicle.





- 5. Record the treatment administered in the field. That information will be passed on when the birds are taken to the rehab centre.

Basic material needed to stabilize birds on beaches is as follows:
- Cloths/gauze.
- Tubes.
- Saline solution.
- Stomach protector.
- Eye protector.

4.6 Transfer to rehabilitation centres

Special care must be taken when transporting birds, as this is stressful for them; serious losses can ensue if a number of basic principles are ignored. The most important is to minimize the time lapse between capture and admission to a reception centre, and therefore regular transportation from the beaches needs to be arranged.

Transport supervisors should patrol their sections of the coast, periodically contacting the search teams to collect the birds that have been caught. These patrols may usefully include personnel qualified to provide first aid to birds. The use of off-road vehicles should be avoided in areas of particular environmental value and sensitivity such as dune vegetation.

Great care must always be taken in transportation. Vehicles must be covered and medium-sized, able to regulate temperature and have a good ventilation system, since depending on the type and freshness of the oil, it may give off vapour that affects occupants and birds. Each bird must be put in a hard-wearing container (cardboard or wooden box, etc.), which can be properly closed to prevent the bird escaping, is dark and has holes for good ventilation (to allow it to breathe and prevent further health risk from toxic oil vapours). The container must be twice the size of the bird it is to hold and the bottom must be well padded with oil-absorbent paper or towels; it should also have 2.5 cm-diameter holes in the upper an lower parts on at least two sides. The holes should be made before putting the bird inside (Figure 12).

The arrangement inside the vehicle must such as to prevent sliding and bumping and to ensure that ventilation holes are not covered; Berg (2003) recommends keeping a minimum distance of 2.5-4 cm. between them. The containers must not be piled up or too many animals moved together (Figure 13).

Should it be necessary to put several birds

Handling an oiled bird: hold the body with both hands, ensuring that the bird can breathe properly.

together, bear in mind that some species are not mutually compatible, which can lead to attacks resulting in fresh wounds and even death. Berg (2003) considers murres (*Uria aalge*), ducks excepting the common scoter (*Melanitta nigra*), mergansers, geese, terns and waders to be compatible species. Birds of other species or groups of species must be separated, especially divers and grebes.
As a general rule, a) do not mix individuals of different species or very different sizes; b) they should be in similar physical condition and equally oiled; c) containers must be checked 5-10 minutes after putting the birds in to ensure that those travelling together are compatible.
Controlling temperature and monitoring the birds are critical during transportation. The temperature inside vehicles must be around 20-21 ºC, although wet birds require between 26-27 ºC to be comfortable (Berg, 2003). Avoid direct sunlight on containers. The birds must be regularly monitored on trips lasting over an hour, and also hydrated on trips lasting over four hours, although it should be borne in mind that too much attention can increase stress levels.
It is important to devise an efficient transportation plan that takes into account the sections being searched and the location of the stabilization and rehabilitation centres. Transporting dead birds must be equally efficient and conducted on a daily basis, taking advantage of trips to transport live birds.

4.7 Releasing rehabilitated birds

It must be the veterinary team that selects which birds are to be released. Releases must be performed at the earliest possible moment, for the longer a bird is out of its habitat the greater are the chances that health problems not directly related with oil will arise, thereby posing a threat to rehabilitation. All released birds must be ringed. The sensitivity maps should be used as a tool to select release areas. For each species or group of species, or at least for the most sensitive species in the geographic ambit of the action, it is advisable to draw up a list of potential release sites. According to Berg (2003), the criteria to be used for the final selection of release sites and conditions are as follows:

- There must be no oil.
- Minimize the risk of birds being re-oiled.
- Same geographic area as capture site if possible (special attention must be paid to limiting factors connected with the social behaviour of species such as the crested cormorant).
- Release should take place in the right period according to local phenology of each species (especially in the case of migratory species).
- Availability of accessible uncontaminated food.
- Minimal human disturbance (vessels, noise, etc.) in the area.
- Area protected from adverse climatic conditions.
- Favourable climatic conditions and weather forecast.
- Right time of day for the species. As a general recommendation releases should be early in the morning after the animals have fed; it is

advisable to be alert to bird behaviour after release throughout the day, so that birds having problems may be recaught.

- Minimal logistical requirements for transport. Release sites as close as possible to rehabilitation centre.

A monitoring programme for released birds is advisable to ascertain how many of them are eventually reincorporated into the population, and to establish the real effectiveness of rehabilitation work. Monitoring can provide useful information that results in improvements in recovery criteria and processes.

ANNEX I

Brief introduction to Spain's seabirds

For each species group, basic information is provided regarding the number of taxa included in it, status, distribution and numbers, phenology, habits, habitats, and some recommendations and remarks on catching and handling.

a) Divers

Species: great northern diver *(Gavia immer)*, black-throated diver *(Gavia arctica)* and red-throated diver *(Gavia stellata)*.
Status: wintering.
Distribution and numbers: northern third of the Peninsula; very scarce along the coast of Catalonia, absent from the Canary Islands (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: shallow coastal waters, especially bays and estuaries.
Habits: swimming and diving habitats, always remain in the water, tending to form flocks at dusk.
Handling: these are sturdy birds with sharp beaks. Two people are needed to handle a diver; it is crucial to restrain the head. Very prone to become stressed in captivity. As their legs are set very far back on the body, on land they rest on their chest and are liable to injure their keel; transport containers need to be well padded. They may squabble and wound each other in confined spaces. Handlers must watch out for ejected faeces.

b) Grebes

Species: a notable species, black-necked grebe *(Podiceps nigricollis)*.
Status: Species resident in mediterranean and andalusian atlantic sectors, where

they breed; winter on the cantabrian and galician coasts.
Distribution and numbers: mainly along the mediterranean coasts and on the Atlantic coast of Andalusia; scarce on the cantabrian and galician coasts (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: normally frequent coasts, but also strongly associated with wetlands, where they breed.
Habits: a diver and quite gregarious, always stays in the water.
Handling: medium-sized. As their legs are set well back on their body, when on land they rest on their chest and are prone to injure the keel; transport containers need to be well padded. They may fight and injure each other in confined spaces. Handlers must watch out for ejected faeces.

c) Shearwaters

Species: greater shearwater *(Puffinus gravis)*, sooty shearwater *(Puffinus griseus)*, Cory's shearwater *(Calonectris diomedea)*, manx shearwater *(Puffinus puffinus)*, balearic shearwater (*Puffinus mauretanicus)*, yelkouan shearwater *(Puffinus yelkouan)* and little shearwater *(Puffinus assimilis)*.
Status: little shearwater and manx shearwater breed in the Canary Islands, where they are summer visitors; the balearic and yelkouan shearwater in the Balearic Islands, where the first is resident; Cory's shearwater in the Canary Islands and the Mediterranean, where it is a summer visitor. The greater and sooty shearwaters appear in northerly parts of Spain on autumn migration to their breeding grounds in the southern hemisphere.
Distribution and numbers: generally common in Spain, although abundance is determined by time of year and region. Great shearwaters and sooty shearwaters are only common on the coasts of the northerly part of the Peninsula (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters.
Habits: pelagic, and great gliders. They only come to land to breed, generally forming small colonies in barely accessible areas such as islets, rocks or cliffs, where they occupy holes, caves and fissures. The balearic shearwater, which is a diving bird, is the most coastal species of all, tending to form rafts all the year round, in proximity to breeding colonies, on migration and when wintering. In the breeding season these species may make long journeys to obtain food, leaving their colonies for several days.
Handling: they have sharp hooked beaks able to inflict painful wound. When alarmed they expel a strong foul-smelling stomach oil through the mouth. They have sturdy legs and sharp nails which can cause injury. On land they rest on their tarsi; transport containers need to be padded.

d) Fulmars

Species: single species, northern fulmar *(Fulmarus glacialis)*.
Status: wintering.
Distribution and numbers: found on the cantabrian and galician coasts (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters.
Habits: pelagic, feeding on sea surface.
Handling: they have a sturdy beak with which they can inflict painful wound. When alarmed they expel a strong foul-smelling stomach oil through the mouth. On land they rest on their tarsi; it is advisable to pad out transport containers.

e) Petrels

Species: Bulwer's petrel *(Bulweria bulwerii)*, storm petrel *(Hydrobates pelagicus)*, band-rumped storm-petrel *(Oceanodroma castro)*, white-faced storm petrel *(Pelagodroma marina)* and Leach's storm-petrel *(Oceanodroma leucorrhoa)*.
Status: the first four breed in the Canary Islands, where they behave as summer visitors. Of the first four, only the storm petrel breeds away from the Canaries, both on the cantabrian and galician coasts and in the Levant and the Balearic Islands, where it behaves as a resident species. Leach's storm-petrel occurs in autumn and winter.
Distribution and numbers: found in all three geographical areas in question, although the largest number of species are found in Canary Island waters. In the Mediterranean only the storm petrel is found, and in the Atlantic it is joined by Leach's storm-petrel (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine surfaces.
Habits: flying species frequenting open seas and only coming to land to breed. Forms colonies on marine rocks at the foot of coastal cliffs, except for the white-faced storm petrel, which does so among dunes; nests under blocks of rock or plants, in cracks, small galleries and holes.
Handling: small, need to be handled gently.

f) Gannet

Species: single species, northern gannet *(Morus bassanus)*.
Status: wintering and migratory.
Distribution and Numbers: very widely distributed on the atlantic coast and in the Mediterranean, although in the Canary Islands it is only found on Lanzarote, Fuerteventura and Gran Canaria; there is no precise information on numbers although there are estimated to be several thousand off the coasts of Spain.
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters.
Habits: pelagic, flying species, dives from the air to feed and only perches or roosts on land in the breeding season.
Handling: large wide pointed beak capable of inflicting painful wounds. Two people are needed to handle one bird; it is essential to restrain its head.

g) Cormorants

Species: crested cormorant *(Phalacrocorax aristotelis)* and great cormorant *(Phalacrocorax carbo)*.
Status: the crested cormorant is a breeding and sedentary species, while the great cormorant is chiefly a wintering species.
Distribution and numbers: there are two known subspecies of crested cormorant, the nominal *aristotelis*, restricted to the cantabrian and galician coasts, and *desmaresti*, which inhabits the Mediterranean. Neither is found in the Canary Islands (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: the crested cormorant is strictly coastal; the great cormorant is also found on inland wetlands in the Iberian Peninsula.
Habits: swimmers and divers, they spend a lot of time in the water but have diurnal perches and roosts on land. The crested cormorant nests on inaccessible coastal cliffs, mostly on islands and islets near the coast where they form colonies of varying size. They are gregarious, sometimes forming large feeding flocks.
Handling: medium-large, with long neck and hooked beak. They must be allowed to breathe through the mouth as they do not have external nostrils in the beak. Restrain the head at all times as they can attack and cause serious injury.

h) Sea ducks

Species: single common species, common scoter *(Melanitta nigra)*.
Status: autumn and winter migrant.
Distribution and numbers: distributed along the atlantic and mediterranean coasts; very rare in the Canary Islands (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: mainly occupy coastal areas with shallow water such as beaches and bays.
Habits: swimmers and divers, at this latitude they stay in direct contact with the water.
Handling: medium-sized, they are prone to external injuries to the feet and joints; transport crates need to be padded. Often go limp when handled, which does not necessarily mean they are in a critical condition; they may also be very aggressive, hissing and attacking, but their pecks are not dangerous to handlers. When transporting them, bear in mind that males of this species may be aggressive to females and juveniles.

i) Phalaropes

Species: single species, usually present, red phalarope *(Phalaropus fulicarius)*.
Status: autumn and winter migrant.
Distribution and numbers: chiefly off the atlantic and galician coasts. No precise information on numbers.
Phenology: see Figures 2, 3 and 4.
Habitats: non-coastal marine waters.
Habits: pelagic.
Handling: small and delicate, requires careful handling and is very prone to hypothermia.

j) Skuas

Species: great skua *(Catharacta skua)*, parasitic skua *(Stercorarius parasiticus)*, pomarine skua *(Stercorarius pomarinus)* and long-tailed skewer *(Stercorarius longicaudus)*.

Status: autumn migrants
Distribution and numbers: most numerous off the cantabrian and galician coasts; the long-tailed skua is not found in the Canary Islands. No precise data on numbers.
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters.
Habits: flyers, pelagic, they pursue other seabirds to steal food.
Handling: strong beaks, especially the great skua, with which they can give painful wounds; the head must be restrained.

k) Gulls

Species: Mediterranean gull *(Larus melanocephalus)*, little gull *(Larus minutus)*, black-headed *(Larus ridibundus)*, slender-billed (Larus genei), Audouin's (*Larus audouinii)*, common gull *(Larus canus)*, black-legged kittiwake *(Rissa tridactyla)*, Sabine's gull *(Larus sabini)*, yellow-legged *(Larus michahelis)*, lesser black-backed *(Larus fuscus)* and great black-backed *(Larus marinus)*.
Status: all breed in Spain, except the little, common and Sabine gulls; the latter appears during autumn migration on the cantabrian and galician coasts; the black-legged kittiwake is chiefly a wintering species, as are the common, little, Mediterranean, black-headed and great black-backed gulls. Slender-billed and Audouin's gulls are resident, although the latter also present partial migration to the atlantic coasts of North Africa. The yellow-legged and lesser black-backed are also resident, although several thousand of the latter species come in winter from European countries.
Distribution and numbers: Mediterranean, black-headed, Audouin's and slender-billed gulls breed only in the mediterranean region, although the latter also on the atlantic coast of Andalusia, while the great black-backed gull does so only in Galicia. In the Canary Islands there are only black-headed and lesser black-backed gulls, while the slender-billed and Audouin's gulls are confined almost exclusively to the mediterranean region (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters and all kinds of coastal environments.
Habits: all are flyers and feed on the surface of the water. The Black-legged kittiwake and Sabine's gull are pelagic, while the rest mainly frequent the coast, where they have perches and roosts. They seek food along the coast and out to sea, where they often follow fishing fleets to pick up discards. A very gregarious species, sometimes forming large flocks. They form dense breeding colonies on little-frequented islands or rocky islets, although slender-billed gulls breed in shallow brackish and salt-water marshes.
Handling: the larger species such as the great black-backed, Audouin's, yellow-legged and lesser black-backed gulls all have sharp beaks; usually aggressive and can injure handlers. Head needs to be restrained.

l) Terns

Species: the most common are the gull-billed tern *(Gelochelidon nilotica)*, sandwich tern *(Sterna sandvicensis)*, common *(Sterna hirundo)* and Arctic *(Sterna paradisaea)* terns, little tern *(Sterna albifrons)*, and black *(Chlidonias niger)* and whiskered terns *(Chlidonias hybridus)*.
Status: all breed in Spain, except for the Arctic tern, which is migratory. The sandwich tern is resident in the Mediterranean and migratory and wintering on the peninsular atlantic coasts and the Canary Islands. The common tern is a summer visitor in the Mediterranean, migratory on the atlantic coast and resident but very scarce in the Canary Islands. The gull-billed tern, little tern and others are migratory and summer visitors in the Mediterranean, and migratory on the atlantic coasts, although the gull-billed tern is generally a rare migrant.
Distribution and numbers: all are found on the atlantic and mediterranean coasts, but in the Canary Islands only the common and sandwich terns are common. Arctic terns are only recorded off the cantabrian and galician coasts (see Table 4).
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters in migration, and in all kinds of environments along the coastline.
Habits: flyers and poor swimmers; they feed on the surface of the water at the shoreline; terns' association with the sea is restricted to the season when they move to their African wintering grounds. They are gregarious species, resting on land, where they may form large mixed flocks with other species such as gulls. Breeding colonies can be found on coastal wetlands, islands of coastal salt-water lagoons, coastal sandy stretches or on floating vegetation (terns).
Handling: small to medium-sized, they have sharp beaks and require careful handling.

m) Alcids

Species: Common murre *(Uria aalge)*, razorbill *(Alca torda)*, Atlantic puffin *(Fratercula arctica)* and little auk *(Alle alle)*.
Status: wintering. Only the murre breeds in Spain; there is a single colony in Galicia, with very few pairs; in practice it may be regarded as extinct as a breeding species.
Distribution and numbers: in the east Mediterranean the puffin and the razorbill are found, and in the Canary Islands only the puffin. There are no precise data on

numbers, but they are estimated to be very numerous, especially on the cantabrian and galician coasts, except for the little auk, which is much scarcer.
Phenology: see Figures 2, 3 and 4.
Habitat: non-coastal marine waters, except for the razorbill; also present in a wide variety of environments along the coastline, such as large bays, inlets and estuaries.
Habits: all swimming species that feed by diving, remaining in contact with water outside the breeding season. The most coastal is the razorbill, while the puffin and little auk are the most pelagic. May form large flocks.
Handling: their legs are set quite far back although they are able to stand upright; tend to lay down resting on their tarsi, so transport containers should be springy. Prone to foot and joint infections. They can be aggressive, so care must be taken with their sharp beaks.

ANNEX II

Techniques to prevent birds from becoming oiled

A number of techniques have been used in different parts of the world to prevent birds from becoming oiled, e.g. visual, auditory and sensory deterrence of various kinds, as well as preventive capture. Deterrent techniques are useful if in the immediate environs there are alternative habitats in good condition to which the species can be scared away; these techniques work better in small, well-defined areas like bays, inlets or quays, and in small-scale accidents. Berg (2003) notes that most actions to scare off birds are probably not effective in areas over 7-10 miles. Lehoux & Bordage (2000) develop and discuss this kind of technique in detail, although a summary can be found in Berg (2003). However, few technical documents realistically analyse and assess the effectiveness of these measures. The strategy underpinning preventive capture is to remove birds before they become oiled. These are complex, costly programmes that require strong justification and good planning. Before such a measure is implemented, there are a number of very important issues that must be addressed and evaluated, at least as regards a) the importance of the action for conservation of the species; b) ease and viability of capture; c) risk of injury or loss through stress or accident; d) possible existence and importance of behaviour-related limiting factors; e) experience in captive husbandry; and d) estimated time spent outside their natural habitats.
Preventive captures have proved their worth in penguins, which are generally very gregarious and easy to catch compared with other seabird species. During the accident involving the *Treasure* in June 2000 in South Africa, 19,500 African penguins of the vulnerable *Spheniscus demersus* species (IUCN, 2004) were translocated

Table 4. Abundance of the most common seabird species in Spain during breeding and wintering (based on Madroño *et al.*, 2004 and Martí & del Moral, 2003). Key for wintering: 1= <100; 2= 101-1000; 3= 1001-10000; 4= 10001-100000; 5= >100000; n.q.= not quantified A.= peninsular atlantic; M.= mediterranean coast; C.= Canary Islands. Breeding species are marked in bold.

BIRDS SPECIES	BREEDING			BIRDS WINTERING		
	A.	M.	C.	A.	M.	C.
Red-throated diver *(Gavia stellata)*	-	-	-	1	1	-
Black-throated diver *(Gavia arctica)*	-	-	-	1	1	-
Great northern diver *(Gavia immer)*	-	-	-	2	1	-
Black-necked grebe *(Podiceps nigricollis)*	1000-2000	300-550	-	2-3	2-3 -	
Northern fulmar *(Fulmarus glacialis)*	-	-	-	n.q.	n.q.	-
Bulwer's petrel *(Bulweria bulwerii)*	-	-	1000	-	-	n.q.
Cory's shearwater *(Calonectris diomedea)*	-	10000	30000	n.q.	-	n.q.
Greater shearwater *(Puffinus gravis)*	-	-	-	n.q.	-	n.q.
Sooty shearwater *(Puffinus griseus)*	-	-	-	n.q.	-	n.q.
Manx shearwater *(Puffinus puffinus)*	-	-	200	n.q.	-	-
Balearic shearwater *(Puffinus mauretanicus)*	-	1750-2125	-	n.q.	n.q.	n.q.
Little shearwater *(Puffinus assimilis)*	-	-	400	n.q.	-	n.q.
Yelkouan shearwater *(Puffinus yelkouan)*	-	100-150	-	n.q.	n.q.	-
Wilson's storm-petrel *(Oceanites oceanicus)*	-	-	-	n.q.	-	n.q.
White-faced storm-petrel *(Pelagodroma marina)*	-	-	50-60	n.q.	-	-
Storm petrel *(Hydrobates pelagicus)*	1175-2590	3830-5310	1000	n.q.	n.q.	n.q.
Leach's storm-petrel *(Oceanodroma leucorhoa)*	-	-	-	n.q.	n.q.	n.q.
Band-rumped storm-petrel *(Oceanodroma castro)*	-	-	550-600	n.q.	-	n.q.
Northern gannet *(Morus bassanus)*	-	-	-	n.q.	n.q.	n.q.
Great cormorant *(Phalacrocorax carbo)*	-	-	-	3-4	3-4	-
Crested cormorant *(Phalacrocorax aristotelis)*	3000	1390	-	3	3	-
Common scoter *(Melanitta nigra)*	-	-	-	2-3	1	-
Red phalarope *(Phalaropus fulicarius)*	-	-	-	n.q.	-	n.q.
Pomarine skua *(Stercorarius pomarinus)*	-	-	-	n.q.	n.q.	n.q.
Parasitic skua *(Stercorarius parasiticus)*	-	-	-	n.q.	n.q.	n.q.
Great skua *(Catharacta skua)*	-	-	-	n.q.	n.q.	n.q.
Mediterranean gull *(Larus melanocephalus)*	-	2-3	-	2-3	3	n.q.
Little gull *(Larus minutus)*	-	-	-	n.q.	n.q.	-
Sabine's gull *(Larus sabini)*	-	-	-	n.q.	n.q.	n.q.
Black-headed gull *(Larus ridibundus)*	250-300	4000	-	4	5	2
Slender-billed gull *(Larus genei)*	130-285	600	-	2	2	-
Audouin's gull *(Larus audouinii)*	-	16957	-	1	2	-
Lesser black-backed gull *(Larus fuscus)*	317	89	-	5	4	n.q.
Yellow-legged gull *(Larus michahellis)*	66000	33566	4037-4656	5	4	3
Great black-backed gull *(Larus marinus)*	1	-	-	2	1	1
Black-legged kittiwake *(Rissa tridactyla)*	18-20	-	-	n.q.	n.q.	n.q.
Gull-billed tern *(Gelochelidon nilotica)*	400-2300	200-300	-	1	1	1
Sandwich tern *(Sterna sandvicensis)*	-	3000	-	3	3	2-3
Common tern *(Sterna hirundo)*	1-8	5800-11000	38-51	n.q.	n.q.	n.q.
Arctic tern *(Sterna paradisaea)*	-	-	-	n.q.	n.q.	-
Little tern *(Sterna albifrons)*	3250-4000	1000-1250	-	n.q.	n.q.	-
Whiskered tern *(Chlidonias hybridus)*	5300-6300	2852	-	n.q.	n.q.	-
Black tern *(Chlidonias niger)*	15-30	-	-	n.q.	n.q.	n.q.
White-winged tern *(Chlidonias leucopterus)*	-	-	-	-	n.q.	-
Common murre *(Uria aalge)*	1	-	-	n.q.	n.q.	-
Razorbill *(Alca torda)*	-	-	-	n.q.	n.q.	-
Little auk *(Alle alle)*	-	-	-	n.q.	n.q.	-
Atlantic puffin *(Fratercula arctica)*	-	-		n.q.	n.q.	n.q.

and released 800 km from their breeding colonies to prevent their being oiled (Crawford *et al.*, 2000). Translocation was also useful in the case of the little blue penguin *(Eudyptula minor)* in the *Iron Baron* accident in Tasmania (Hull *et al.,* 1998). During the *Prestige* accident the idea of preventive capture of crested cormorants *(Phalacrocorax aristotelis)* was mooted but ruled out as impracticable and probably ineffective.

ANNEX III

Risks of handling wildlife

Wild animals feel threatened in the presence of people, and sometimes their natural response is aggression. They may therefore cause injuries –sometimes considerable– with their beaks, nails or wings, which must be treated swiftly to prevent infection. Birds must always be kept at or below waist height to protect the handler's face and eyes.
Also, diseases caused by viruses, bacteria, fungi and parasites can be transmitted by wildlife in general. However, according to White *et al.* (1998) transmission is rare. Disease can be transmitted to people by four main routes: a) inhalation of particles in the air (spores, bacteria); b) ingestion of excrement (ejected faeces, poor hygiene); c) through the skin; and d) indirectly via a vector (bite/insect bite, bee sting) (Berg, 2003).
Salmonella poisoning can also be contracted by accidentally ingesting faeces. Other bacterial infections may be more serious and are caused by the exposure of open wounds to bacteria in the animal's skin, feathers, excrement, saliva or blood. Although rare, there is a chance of hepatitis and tetanus. All personnel must be warned and informed of the necessary prophylactic measures, in this case vaccination. All lesions and diseases must be treated as swiftly as possible under medical supervision. White *et al.* (1998), provides a list, reproduced in Berg (2003), of the most common diseases, with information about transmission, most common origin, groups of species affected, symptoms and precautions to be taken when handling. Special attention should also be paid to developments in avian flu.
The best defence against zoonoses is good hygiene and common sense. People who are sick, pregnant or on medication, and whose natural defences may therefore be low, should not work with oiled wildlife as they are more susceptible to contracting a disease. There is also a risk of passing on disease to poultry and to domestic and farm animals via clothing or equipment that has been in contact with wild birds. The presence of domestic animals must be prohibited during rescue and translocation work. All protective material and equipment must be decontaminated in accordance with the procedures laid down in the current regulations.
(Based on White *et al.*, 1998; Berg, 2003 and IPIECA, 2004).

ANNEX IV

Brief comments on safety and health

Adequate personal health and safety gear is essential before any capture operation commences. The minimum recommended equipment for coastal inspections includes the following:

- Oilproof overalls.
- Anti-slip waterproof and oilproof footwear.
- Protective goggles.
- Waterproof and oilproof nitrile rubber or neoprene gloves suitable for protection against pecks and scratches.
- Breathing protectors (as indicated by medical staff).

Do not let skin, face or eyes come into contact with oil, cleaning products or contaminated equipment. Before eating, drinking or smoking, remove protective equipment and wash hands and face carefully with soap and water even if you used gloves. Never do so where birds are being handled or near oil.

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Handbook 3: Procedure for cleanup of rocky areas and infrastructures by washing with pressurized water jets

Handbook 4: Procedure for cleanup of beaches with buried layers of oil

Handbook 5: Procedure for cleanup operations on impacted shoreline vegetation and areas of secondary pollution

Handbook 6: **Procedures for the cleaning of pebble and cobble beaches**

Handbook 7: Procedure for action using bioremediation techniques in rocky environments impregnated with fuel-oil

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Handbook 8: Recommendations for collecting and transporting oiled birds

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