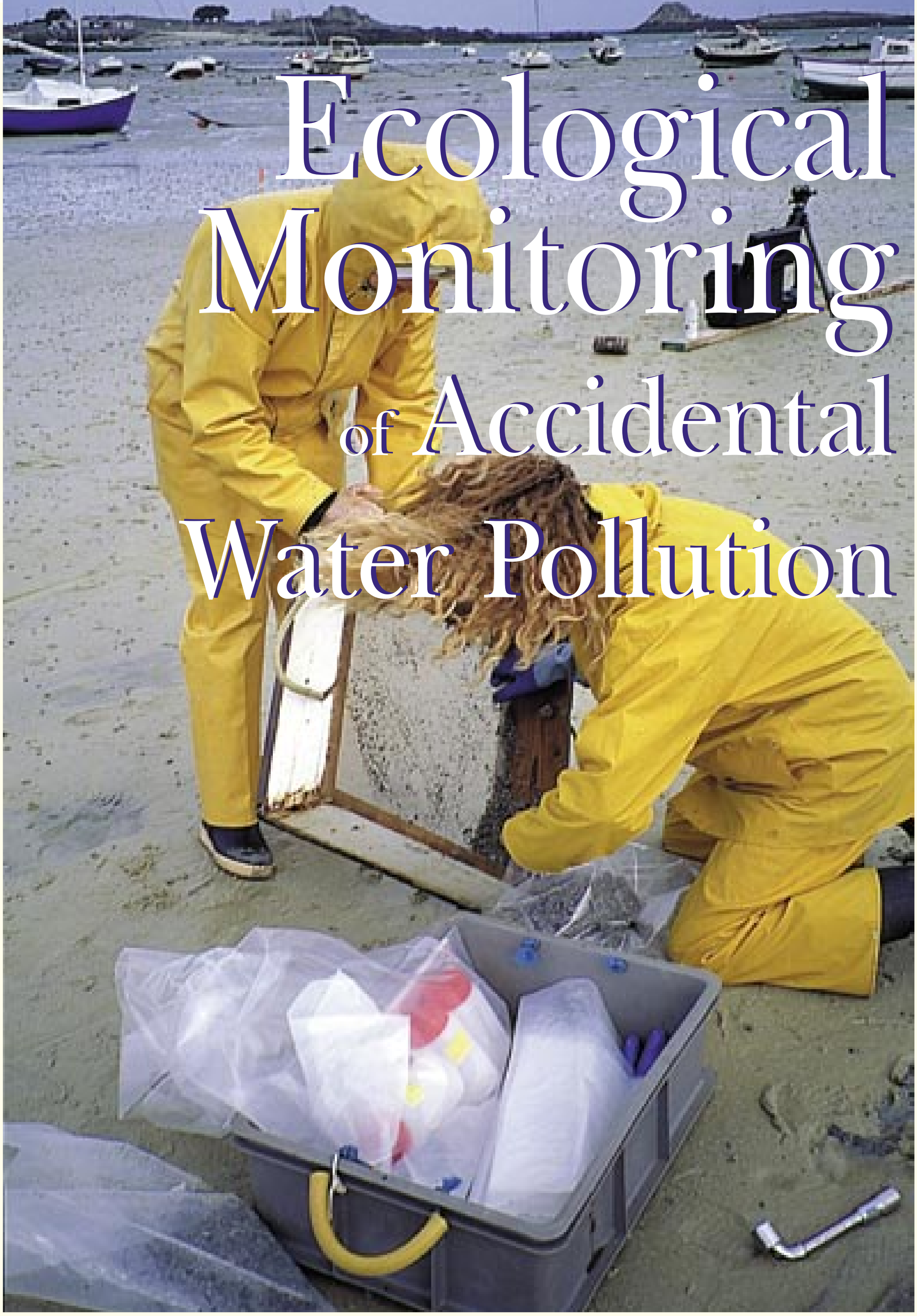
Ecological Monitoring of Accidental Water Pollution



OPERATIONAL GUIDE

Cedre

Cover photo:
*Biological sampling of sediment (*Cedre*).*

Ecological Monitoring of Accidental Water Pollution

OPERATIONAL GUIDE

DESIGNING, MANAGING AND CONDUCTING A MONITORING PROGRAMME

Guide produced by the Centre of Documentation, Research and Experimentation on Accidental Water Pollution (*Cedre*) as part of its technical programme, with financial support from the French Ministry of the Environment and the company Total Fina Elf.

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Purpose of this guide

This guide is aimed at **decision-makers liable to be involved in designing and implementing ecological monitoring programmes in the aftermath of an accidental water pollution incident**. It is designed more particularly for the public sector, however all decision-makers will doubtlessly find useful material within this document.

When a medium- to large-scale pollution incident occurs, it is generally assumed that the response plan will include health, ecological and economic monitoring programmes, to examine the long term consequences of the spill. It is taken for granted that these programmes will be implemented by the State at the polluter's expense.

This is more or less what happens in the US, where specific national legislation (Clean Water Act, Comprehensive Environmental Response and Liability Act, Oil Pollution Act) establishes the principle of "punitive damages" that the polluter must pay into specific funds, managed by mainly public administrators. Proposals of studies and actions from all sources are presented to these funds and those considered most suited to establishing the extent of the damage and carrying out rehabilitation operations are selected by the administrators.

The situation is however somewhat different in most other countries. Law on water pollution in the majority of European countries indeed allows for the possibility of condemning a polluter to restore the environment to its original state, if necessary with penalties if the deadline is not kept. However, it does not always make mention of the funding and organisation of studies designed to establish the exact nature of the impact on the environment and determining the work to be carried out. The State must therefore take on these expenses, and then reclaim them from the party liable for the pollution.

This raises many questions for those who find themselves responsible for these tasks. **Who decides? Who manages? Who conducts the studies? What is the aim? What budget is provided? In what conditions? What are the limits?** By providing answers to these questions, this guide aims to supply practical indications on how to design and conduct ecological monitoring programmes in a way that will be beneficial all around.

Without going as far as taking the extreme case of the *Exxon Valdez* oil spill in Alaska which attracted a huge amount of media attention, the reader can find out more about the running of the US environmental damages funds, their objectives, their financing and their operators by visiting the website of the Damage Assessment, Remediation, and Restoration Program (DARRP) of the National Oceanic and Atmospheric Administration (NOAA) at the address www.darrp.noaa.gov. Today these funds are the worldwide standard discussed at international congresses. For the reasons outlined above, this practice cannot be directly transposed for other countries. It is therefore important to be wary of imagining such as set-up in contexts different from that of the US.

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A

Emergency actions

Every accidental pollution incident sparks off a similar series of questions. How badly is the environment contaminated? What will be the long term consequences on the flora and fauna? Will the populations return to their original state? If so, how long will it take? Can we help to promote this restoration? If so, how? In addition to these general questions, issues concerning the use of the natural environment and its resources are also raised. Have the use of the environment by humans and the consumption of natural resources become dangerous? Decisions with significant repercussions, such as closing off a beach or banning fishing or the sale of sea produce, must be made without delay.

Action must be taken quickly and carefully. Measures must be taken to establish a reference condition before the pollution arrives, while it is still possible. Decision-makers must be persuaded of the soundness of environmentally friendly response methods. Realistic predictions must be communicated to the general public, based on a careful use of data from previous pollution incidents. When the time comes, clear and complete information on the actual environmental impact must also be produced. **As with all other fields of pollution response, the aim of ecological monitoring is two-fold: on the one hand, it must cover the urgent operational needs of the emergency and, on the other hand, it must also establish an objective global overview.** These two elements are subject to different constraints. For the first element, the timeframe takes precedent, even if it means that this stage cannot be completely exhaustive. For the second element, the exhaustive nature is of greater importance, even if it means provisionally having to produce a number of working documents before gathering all the information in an overall review.

Mobilising agents

As soon as an oil spill or other form of accidental pollution occurs, an ecological monitoring programme will be set up: measuring the environmental impact is an indispensable tool for making decisions about response options, implementing restoration techniques and informing the public. However, no-one can clearly tell the scientists who will mobilise them, under what contractual conditions and when.

The administrative and budgetary implementation of ecological monitoring is not currently predefined in pollution response contingency plans. The urgent mobilisation of the necessary competent agents remains a major hurdle, in particular when it comes to establishing reference conditions. **It is each competent team's responsibility to decide on its implication, without any guarantee of financing, in order to contribute to the overall action of conserving the environment.** Once they are in action, the teams will naturally turn to the State's ministry for the environment: practice has shown that this ministry is generally the coordinator and main financer of ecological monitoring in the event of a pollution incident. The ministry will then claim reimbursement from the party established as liable for the pollution.

The media will not lose any time in mobilising their own environmental experts and will rapidly declare what is at risk. These press cuttings from the days following the grounding of the oil tanker the *Sea Empress* in Wales demonstrate this phenomenon.

Ecological monitoring requires more time and effort than the media tend to claim. The *Amoco Cadiz* oil spill (1978) mobilised many scientists to assess the impact of what remains the largest ever oil spill due to an oil tanker grounding. The first ecological monitoring programme for this pollution, a project which lasted three years, was funded by the French Ministry of the Environment. Other programmes, with other contributions, were later added.

When the *Erika* oil spill occurred (1999), neither the French national POLMAR instruction, a text which governs pollution response, nor the rules of the International Oil Pollution Compensation Funds (IOPC Funds) yet determined the content and the sources of funding of ecological monitoring for this type of pollution. However, as with the *Amoco Cadiz*, this monitoring was imposed and an initial five year monitoring programme was financed by the French Ministry for the Environment.

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Establishing reference conditions

The contamination of the environmental and the ecological impact of a spill can only be validly appreciated based on reference values accurately establishing the situation before the accident. The environment is very rarely free from the effect of chronic pollution, or sometimes even the remains of previous accidental pollution incidents. If it so happens that an environmental study of the area has just been conducted, the measurements, tests and samples can contribute to the reference condition. However, in most cases, immediate measurements or samples must be taken to establish important points of the reference condition.

There is no need for lengthy debates to determine what must be measured, photographed or sampled before the pollution arrives and kept in a safe place for subsequent use. The local specialists will know what is necessary. Extensive means are required for sampling at sea. On the foreshore, only modest means are needed. **This urgent task will therefore not be delayed by the implementation of a formal environmental monitoring framework.** It can be conducted by State service agents, universities, research institutes, associations or municipalities without waiting for orders, by simply collecting data and samples to reduce the immediate costs.

Those who embark upon such actions without instruction to do so, whether this comes under the umbrella of their public service mission or because they deem themselves competent in this field, should immediately inform the operational response centre. In return, they can be informed in real time of the pollution's characteristics, the progressive impact, the tests in progress and studies begun on the pollutant's weathering in the laboratory and in the natural environment. They can also receive written confirmation of their involvement in a structured approach by the relevant operational response centre, an important element for subsequently obtaining reimbursement for the expenses incurred, and may obtain the assistance of an accredited agent where necessary.

Ideally, the information gathered in reference conditions should be coherent with the needs of the ecological monitoring in the long term, in order to provide the basis for an objective impact report. If there is no prior agreement, which proves difficult to come to in an emergency situation, a good knowledge of what will be required for medium and long term monitoring is necessary.

An accidental pollution can almost always be compared to a similar previous spill, either in the same country or overseas. Archives of these incidents and their consequences can be accessed through various bodies such as research institutes, associations and universities, which generally have a website. Local specialists who contribute to establishing a reference state in the event of an emergency can very rapidly access reliable information in practices elsewhere in their field of expertise, through these websites and archives.

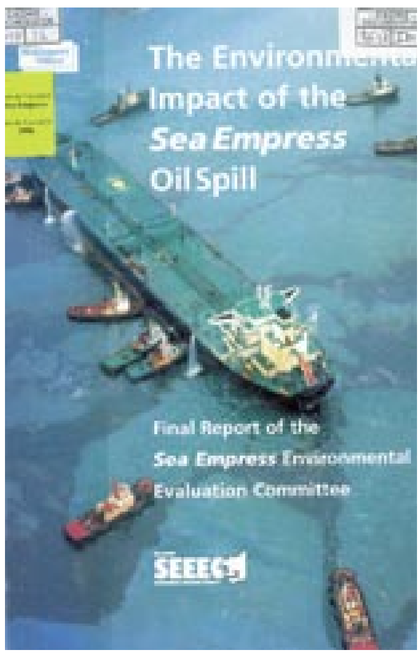
Building a framework

A3

Once the first specialists have begun working on reference conditions in their field of expertise, it soon becomes a priority to arrange financial means, to establish interfaces and to organise actions in the field and in the laboratory. In the absence of a predetermined operational structure to initiate and direct environmental impact assessment, determining and implementing this structure are a part of the responsibilities of the authorities in charge of response. These authorities are generally overloaded with work due to the emergency in hand and lack the time needed to dedicate to ecological monitoring, whilst being aware that public demand concerning this subject is urgent and high.

The experience of the *Erika* spill in France highlighted the key role of DIREN, the Regional Directorates for the Environment. These directorates are decentralised services of the French State, working under the authority of the Ministry of Ecology and Sustainable Development and Planning. It was upon their initiative that the environmental steering committees for ecological monitoring were set up, which, alongside *Cedre*, carried out the necessary surveying and sampling. They also ensured permanent dialogue with response operators on the limits which should not be exceeded to prevent exacerbating the impact already caused by the pollution itself.

In the UK, the Ecological Steering Group on the Oil Spill in Shetland (ESGOSS) was set up by the Secretary of State for Scotland in the aftermath of the *Braer* incident (Shetland, 1993) and the Sea Empress Environmental Evaluation Committee (SEEECS) by the Secretary of State for Wales after the *Sea Empress* spill (Milford Haven, 1996). The final reports of ESGOSS and SEEECS were published in 1994 and 1998 respectively. The SEEEC report stated that the environmental monitoring work from the beginning of the pollution was directed by the environmental team of the Joint Response Centre, rapidly supported by the initiatives of the Countryside Council for Wales for birdlife and the Ministry of Agriculture, Fisheries and Food for marine resources, with many of the organisations involved using their own resources. The SEEEC was officially set up eight weeks after the spill occurred.



Sea Empress *spill: cover of the final SEEEC report.*

Setting up a monitoring programme

B

If urgent mobilisation can currently only be based on the initiative and means of intervention teams, it quickly becomes necessary to supply and organise the work through the implementation of specific funding, the definition and continual adaptation of precise objectives and the organisation of work without unnecessary duplication or overt insufficiencies.

Logically, this is the task of the main financer, generally the municipality for small-scale pollution or the ministry for the environment for major pollution. This financer is not necessarily the only financer, nor the body in charge of assigning and coordinating response.

In every instance, it must be clear that the funding is designated to field-based impact studies and laboratory-based testing of samples of water, sediment and living matter. The funding must not go into research on the pollutant and its effects, or studies or experiments on the improvement of response techniques, products and strategies. These tasks, important as they are, are not a part of ecological monitoring.

If the data is not already available, the ecological monitoring programme may include establishing the exact nature of the products spilled, checking their behaviour in the natural environment, elaborating the most plausible weathering scenarios and, where relevant, emulsion formation: these elements are indispensable basic pieces of information.

Financial resources

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In the same way as the funding of pollution response in the US and in Europe is not comparable, there is no measure common to the American and the European budgetary dimension of ecological monitoring. There is however one clear point of convergence: the division of the budget by the financer between the teams of scientists, in the form of direct subsidies, which was previously commonplace in Europe, has begun to disappear in favour of competitive calls for proposals, managed by a contractor hired by the financer and assisted by a scientific committee, much like the calls for proposals financed by US funds.

This practice remains relatively infrequent for **small-scale pollution**, in which case there still tends to either be a complete absence of ecological monitoring, or a direct contract between the local financer and a service provider. Calls for proposals are more frequent for **pollutions with regional scope**. They have become almost systematic for **pollution on a national scale**, where various additional sources of funding complement available funds. Private funding may be provided by the party responsible for the pollution or a patron, through direct contracts or funds made available to a public instructing party. There may also be international funding, in particular European funding: contribution to environmental monitoring has now become a systematic proposal of the Environment Directorate-General of the European Commission in the case of major spills.

It is important to be aware of the possible consequences of certain sources of funding. After the pollution monitoring studies in the wake of the *Amoco Cadiz* spill financed by Standard Oil as part of a cooperation agreement between the National Oceanic and Atmospheric Administration (NOAA- USA) and CNEXO (France), in court certain French scientists found themselves faced with American scientists who had used the same data that they had collected jointly in a different manner.

The financing of ecological monitoring after the *Erika* spill was split between different contributions:

- the French Ministry of the Environment, through a special programme called “Suivi Erika”, jointly managed by IFREMER and INERIS, and a branch of the permanent scientific programme “Liteau”, managed by IFREMER, named “Liteau-Erika”
- the regions affected, through the allocation of bursaries and research contracts within the framework of their usual calls for proposals.

Objectives and steering committees

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The objectives of ecological monitoring are not the same for emergency monitoring and scientific monitoring.

Emergency monitoring, during the crisis phase, aims to establish the evolution of the situation in the field on a daily basis, to identify the points at which intervention alongside response teams could help to enforce more environmentally friendly practices and get the necessary message across to responders, and to quantify the immediate moralities (birds, marine flora and fauna). This monitoring targets the problems of the moment, whilst gathering information which will be useful later for scientific monitoring.

Scientific monitoring aims to establish the long term impact of the pollution on the sites, populations and species in the affected area, so as to act as a basis for any environmental restoration operations and to help to establish an objective report.

In the case of a small spill, the steering committee may only be made up of a single person. A national-scale incident may result in a number of different steering committees, each for a different programme, interconnected by common members or by an overall coordination committee. Each steering committee determines the limitations of the exercise it is in charge of, its priorities and its deadlines, according to the rules of the financers and the means provided by them. In all cases, **it is the committee's responsibility to clearly and rapidly determine the outputs of the monitoring programme**: a series of working documents, a final overall report, a permanent section on their website, presentation of results at a conference or meeting etc.

The steering committee, where the financers of monitoring programmes generally preside, is in charge of the choice of partner scientists with the necessary skills and of seeing that the work is carried out correctly. They can be assisted in these tasks by a scientific committee, in charge of evaluating the offers and judging the work carried out.

The final report of the ecological monitoring steering group for the *Braer* oil spill in the Shetlands defined the use of the terms "environment" and "ecology" as follows:

- It used the term "**environment**" to refer to the combinations of physical factors affecting life in general, including human life (i.e. physical environment), or to all that influences plant and animal growth (i.e. biological environment).
- It used the term "**ecology**" to represent the branch of biology which deals with the relationships between organisms and their relationships with the environment. Although the steering group established these nuances, they are aware that **the two terms are more or less synonymous for the general public**. However, it states that the consequences of a pollution are more often formulated in simple terms of impact on certain species than in real ecological terms, which would position the impact observed within the scope of relationships between the species and its habitat.

Organising the work

Ecological monitoring is confronted with four major organisational problems: circulating information of common interest between all participants, respecting the terms of reference and deadlines, taking into account subject areas which provoke little reactivity from the teams of scientists and communicating the information obtained. Although these issues may be relatively easy to handle in the case of monitoring a small spill, they can be a lot more problematic for a major pollution with multiple monitoring programmes, especially if the parties financing these programmes have potentially conflicting interests.

Good transmission of information of common interest between all participants is a clear advantage: the technical, historical and geographical data on the pollutant, its dangerousness, its movements, the samples taken and the response operations respond to common needs for economic and ecological monitoring. These needs are generally poorly catered for, due to a lack of adequate documentary management. The same can often also be said for the necessary assessment of scientific work carried out in the affected area. These documentary needs are one of *Cedre*'s major priorities, which it works to fulfil through its role as a pollution archivist.

Respecting the terms of reference and deadlines and taking into account subject areas which provoke little reactivity from the teams of scientists are well-known problems in the management of all scientific programmes. They are exacerbated by the fact that many decisions are made under pressure due to the restricted timeframe, without allowing time for them to always be well thought through. It is up to the steering committees to pay particular attention to these points and to take charge of their organisation and all the necessary procedures.

Rapid and effective communication on the information obtained is a delicate subject. Steering committees, which are generally unfamiliar with contentious communication, are rarely prepared for this difficulty. It may be advisable to call upon specialised consultants.

An organisational tool: broad but clear terms of reference.

The second point of the terms of reference of the Sea Empress Environmental Evaluation Committee is as follows: *"To ensure that a comprehensive set of monitoring data on environmental distributions and impacts is obtained, taking account of studies by other organisations and the need to avoid gaps and overlaps."*

An organisational challenge: to establish and raise awareness of the actual extent of the pollution.

Two years after the dramatic images of the pollution broadcast by the media, the environmental impact report on the *Braer* oil spill stated that: *"... there are 15 inhabited and over 100 uninhabited islands in Shetland (...) The total length of coastline is approximately 2,000 kilometres (...) the final total affected was 235 km, or less than 12% of the total length of the coastline of Shetland."*

The main components of ecological monitoring

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Every impact report naturally gives priority to the major concerns in the region affected, for instance birdlife in Wales and seafood in Galicia.

After a presentation of the situation and before the final conclusions, the final report by the Sea Empress Environmental Evaluation Committee includes the following chapters: fate of the oil, marine impacts, shoreline impacts, maritime vegetation and agriculture, mammals, birds, oiled bird cleaning and rehabilitation, amenity and archaeology and the clean-up operation.

The report by the monitoring committee for the *Aegean Sea* spill in Galicia, after a presentation of the incident, includes: monitoring of the contamination produced by the *Aegean Sea* incident, consequences for the subtidal benthic macrofauna, assessment of the contamination of mussels, effects on bivalve populations, monitoring of sublittoral benthos, biosedimentary study and microbiological treatments.

Evolution and fate of the pollutant

Independently of all human action, a pollutant spilt in the natural environment is subject to numerous physical and chemical phenomena, in particular evaporation, settling, oxidation, dissolution, emulsification and biodegradation. Even for pollutants made up of a single molecule (e.g. styrene), these phenomena and their interactions in a set of specific conditions are rarely well-known. Interference can become highly complex when the pollutant is a mixture of thousands of compounds (e.g. oil). Furthermore, human intervention for clean-up operations removes part of the product(s) spilt from the effects of the phenomena at work, at different stages of breakdown.

Establishing the exact make-up of the pollutant, monitoring and understanding the evolution of each part of the environment and establishing a full summary of its fate by mass are essential tasks in order to prevent environmental monitoring from neglecting or misunderstanding any important issues. This work can be carried out at its own pace, without continual exchanges with the other parts of ecological monitoring. However, it will always benefit from periodical comparison of results and hypotheses, which will help to readjust the work in progress.

This monitoring of the evolution and fate of the pollutant can require a considerable amount of measurements, samples, tests, specific experiments and comparison of laboratory-based and field-based data. The realisation of such studies and presentation of the findings will logically be divided into three parts:

- a description of the movements and physico-chemical evolution of the pollutant
- an analysis of its fate in each part of the environment (water, sediment, living matter)
- a summary by mass of its recovery during clean-up operations, its disposal and its natural breakdown.

These elements should be brought together in a clear summary of what pollution remains and may still pose problems.

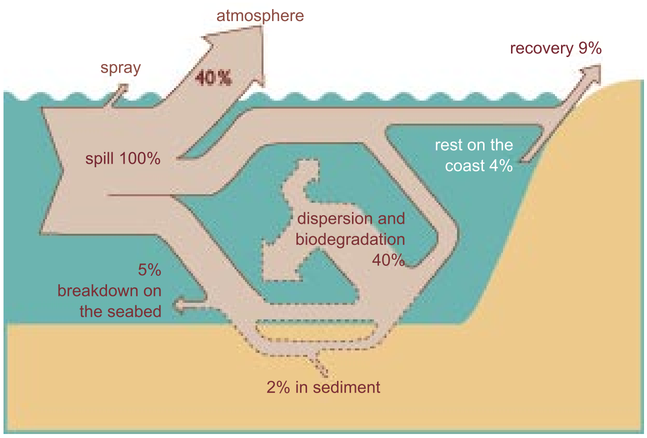


Diagram summarising the fate of the oil spilt during the Amoco Cadiz *incident (data taken from M. Marchand, 1979).*

C2

Shoreline contamination

In rivers, lakes or at sea, the shore (or more precisely the foreshore in tidal areas) is the area where the floating pollutant will naturally be deposited, removed, and then newly deposited. In the vast majority of cases, and in particular in almost all cases of oil pollution, the shore is both the area where most of the pollutant will be concentrated and where most clean-up operations will take place.

We can distinguish emergency monitoring in real time, an element which helps in decision-making for well-planned clean-up operations, and scientific monitoring, to record and measure the impacts.

Emergency monitoring aims to quantify the extent and form of arrivals of pollutant site by site quickly and simply in order to map the pollution on a daily basis, as well as its removal by human intervention or by its remobilisation by the water and any possible repollution. It is also designed to identify any constraints which need to be taken account of to avoid causing any additional impact. It acts as both a real time decision-making tool for clean-up operations and an objective source of information which will serve as a subsequent reference for scientific impact monitoring.

Scientific monitoring aims to determine the long term impacts of the pollution on materials, the environment and the species in the affected area. It requires an in-depth experience of mudflats and gravel pits for fresh waters and mudflats, beaches and rocky foreshores for the marine coastline. It will normally include:

- a detailed account of the progress of contamination of the shore, then of the removal of the pollutant
- a summary of physical and chemical degradation of the shore by the pollutant and its natural or assisted return to normal
- a record of the impacts on characteristic species and the habitats of the different shoreline features, with a summary for each substrate (long term consequences on flora and fauna).

Cedre has published an operational guide entitled “Surveying Sites Polluted by Oil”, which can be downloaded from the website www.cedre.fr. Many documents on the sensitivity of different types of shores to oil pollution, based on their geomorphology and the physical energy which they undergo (winds, tides, currents etc.) are available. They often include vulnerability rankings and average recovery times, based on the experience of past incidents. No documents of this kind exist for pollution by most industrial chemicals.

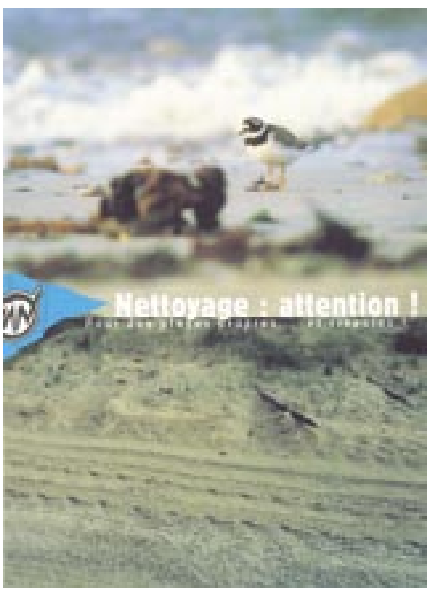
On land contamination

Some may be surprised to find a section dedicated to pollution on land in a guide on accidental water pollution. However, waves and spray or a river bursting its banks may in exceptional cases cause a floating pollutant to be carried to an altitude of several metres and a distance of several hundred metres from a shore or river bank.

Even in relatively calm conditions, it is not uncommon for a slight rise in the water level and even a light wind to cause a certain quantity of pollutant to reach embankments, raised marshland, dune populations or the exposed parts of natural or artificial riprap. Clean-up operations frequently involve men and machinery moving around on sites and temporarily storing waste there. The consequences of this temporary storage are often a major concern in the ecological monitoring of the impact of a spill.

Emergency monitoring in this case consists of operational dialogue with clean-up teams, to prevent them from exacerbating the damage caused by the pollution through inappropriate actions.

Long term scientific monitoring is carried out exclusively by botanists and specialist biologists. Botanical restoration techniques, ranging from simply pruning back vegetation to promote new growth to planting cuttings after cleaning the soil, have now been fine-tuned. Environmental restoration worksites are therefore frequent. Monitoring of pollution on land can be divided into three parts: assessing the damages, planning restoration and then an overall account of natural restoration and operations conducted.



Dunes are a focal point for conflicts between responders and conservationists attempting to protect the natural environment.

In a French booklet on beach clean-up, the *Observatoire des marées noires* uses the clean-up operations conducted on the beaches polluted by the fuel oil from the *Erika* as a reference to warn against removing vegetation at the high tide mark and damaging the foot of dunes. The impact of this spill reinforces these recommendations on more environmentally friendly clean-up of solid waste from beaches, aiming to reduce the risks of regular intensive scraping of popular tourist beaches.

C4

Aquatic contamination

Although the pollution of the shore and the impact on populations living there may often be the most visible and sensitive issues for the general public, pollution of all or part of the water column is of course the fundamental characteristic of any accidental water pollution incident. Monitoring the aquatic contamination is therefore a basic feature of ecological monitoring of this type of pollution.

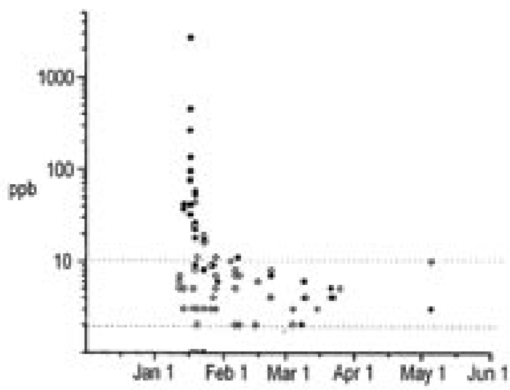
Emergency monitoring involves prioritising gathering information in real time on the movements of the pollutant in the water, including its evolution and the related risks, to provide the response authority with useful information to help in refining a strategy. This involves providing clear answers to difficult questions, such as "should an attempt be made to disperse or sink the floating slicks?" The work is complemented wherever possible by measuring the contamination of the water mass, in relation to the immediate mortalities observed.

Scientific monitoring aims to determine the long term impact of the pollution on the whole of the water column and the populations living there. This is the work of a limnologist for fresh waters and an oceanographer for marine waters, with contributions from the combined skills of physicians, chemists, biologists and ecotoxicologists. Four topics must systematically be studied:

- objective monitoring of the concentration and breakdown (including biodegradation) of the pollutant in the water column
- specific monitoring of the levels of contamination corresponding to the known danger thresholds, for particularly dangerous molecules or reference molecules
- monitoring of bioaccumulation of pollutants and progressive decontamination of aquatic animals and plants
- monitoring of the consequences on the biological balances of the environments and the progressive restoration of these balances.

Emergency monitoring

Should an attempt be made to sink the drifting fuel oil slicks from the *Erika*? The answer to this question from the authority in charge of response in France at the time of the *Erika* spill was provided in real time by *Cedre* in terms of technical feasibility (no – the current state of knowledge does not guarantee reliable or lasting results) and by Ifremer in terms of scientific requirements (no – this would mean exchanging shoreline pollution for pollution of the seafloor, a biologically rich area and an important fishing resource).



Scientific monitoring

The above graph, taken from the environmental impact report for the *Braer* spill in the Shetlands, illustrates the rapid evolution of the presence of polycyclic aromatic hydrocarbons in the flesh of three types of deep-sea fish.

Contamination of the sea or river bed

C5

Unless fishermen bring in fish, shellfish and crustaceans covered in a visible pollutant, such as a very heavy fuel oil or the residue left from a crude oil being burnt, contamination of the sea or river bed tends to be somewhat neglected by environmental monitoring. This type of contamination is not easily perceptible, as it is dispersed over vast sedimentary areas, and is generally subject to little monitoring. It requires complex and costly measuring and sampling programmes. Furthermore, the pollution can only be observed and recorded, while no cure can be provided. In the case of long term impact of the pollution, it is most likely to be on the sea or river bed.

In an emergency, monitoring the pollution of the sea or river bed is crucial in deciding whether to ban fishing of benthic species and, if so, when to drop the ban, decisions which can be difficult when chronic pollution exists and is tolerated on the sea or river bed.

After the emergency, monitoring is important to provide information on the still poorly known phenomena of weathering and biodegradation of pollutants, which are partially anaerobic and slower than on the surface. Monitoring also aims to more fully understand any mechanisms of pollutant accumulation in species and the risks of contamination for humans through the food chain or by fishing bottom-dwelling species.

The slow rate of these phenomena mean that monitoring is necessarily a lengthy process, often involving great difficulty in distinguishing which impacts were brought on by the spill and what is simply background variation due to natural causes or chronic pollution. Ecological monitoring of background contamination necessarily requires many years in order to provide reliable results.

Recovery of fuel oil from the Erika *spill on the seabed by Belle-Ile, France*

© Yves Gladu

Submarine examination of the residues from the burning of the cargo of the Haven *in the Ligurian Sea.*

© IFREMER/ICRAM

Other contamination

All or part of a pollutant spilt into the water may able to evaporate. Those who experienced the *Amoco Cadiz* spill in France in 1978 will no doubt still remember the overwhelming stench of oil as far as several dozen kilometres from the shore. In the case of the shipwrecking of the chemical tanker the *Ievoli Sun* in the Channel in 2000, response coordinators soon realised that they had to pay particular attention to the risk of a sudden release of styrene, which could generate a toxic cloud liable to affect the shoreline. The wind is capable of transporting droplets of non evaporable substances over large distances in the form of vapours.

Air contamination may therefore be an important component of ecological monitoring of a spill. In this field, emergency monitoring essentially involves in situ measurements, movement predictions and protective measures for humans and domestic animals. In addition to professional responders and volunteers, scientific monitoring of long term impact concerns the humans, animals and plants which were downwind of the pollution for a certain duration causing them to be significantly exposed. This type of monitoring is conducted by epidemiologists.

Finally, other forms of contamination may also be considered, in particular **non material deterioration** liable to create negative effects on economic activities or human health. Thus, a major spill can mar the environment's image, leading to a reduction in tourists visiting the area.

This negative image has sometimes been accused of having psychological effects on the local inhabitants.

An example of a two-fold effect: shepherds and sheep oiled by vapours from the Braer *pollution indignant at the special attention paid to birds by the press (final ESGOSS impact report).*

The report from which this cartoon was taken states on the same page: "*There is a feeling for some that action, in the form of survey and monitoring work, is a contribution which can be made towards remedying the devastation which has been visited on them.*" .

Environmental impact studies are an important element in the crucial task of restoring the area's image and then rebuilding trust after a major spill.

Sensitive subjects

Of all the resources affected by a pollution incident, certain biotopes and populations are more apparent than others: images of dead oiled birds or mammals on beaches broadcast by the media are far more likely to shock the public than the silent and inconspicuous death of a bottom-dwelling fish for instance. Coastal marshes, mangrove swamps, sea grass fields and coral reefs have been sensitive topics in terms of the conservation of the marine and coastal environment for a long time. The impact on them will provoke a far more violent reaction than impact on less symbolic biotopes. Response operations themselves, often initially considered insufficient, prove, as the weeks go by, to bring risks of additional degradation which must be restricted.

Restoration techniques for the damage caused are available today for these sensitive issues. Examples of their implementation in the case of accidental pollution can be put forward. For these sensitive areas, **ecological monitoring will often be required to include an additional task: to define the need for restoration where applicable and determine the parameters.**

Impact on birds and mammals

D1

Aquatic birds and mammals both come into regular contact with the air-water interface, birds to feed and to rest and mammals to breathe. An oil spill or spill of another floating pollutant will therefore immediately affect them to a great extent.

Oil pollution has an immediate smothering effect which impairs birds' ability to fly and their thermal insulation. Furthermore, the oil can affect their eyesight (irritation) and can often be ingested in considerable quantities (by cleaning their feathers with their beak). These impacts can lead to many birds being rapidly killed by the effects of the spill. Mammals also suffer from impaired eyesight and absorption of oil, and those with fur also suffer from oiling of their coat.

The immediate worry concerns the species the most in contact with the air-water interface, in particular birds which dive to feed. Special attention is also paid to populations whose balance had been affected by previous impacts: will the pollution leave enough breeders, or enough young from the current generation, to form the minimum stock needed to survive? The first task to be carried out in an impact study on these organisms is to **count and list the dead organisms deposited on the shore by species and age**.

The second obvious task is to **extrapolate the individuals that may have died but were not found**, using as accurate as possible a method. There are numerous examples of such studies.

Over and above the assessment of these more obvious impacts, it must be determined **whether the resistance of a population to illness and its reproductive capacity have been affected** in a quantifiable manner and if repopulation programmes could help to remedy this impact.

This implies long studies, based on carrying out autopsies on corpses and observations and analyses of captured animals. These studies must be carried out carefully, as many external factors could interfere with the effects caused by the pollution.

The oil spill caused by the *Sea Empress* in Wales (1996) occurred in an important area for seabird reproduction and hibernation. An exceptional amount of rescue operations and studies on marine avifauna and mammals were funded and carried out, for an overall cost of £750,000:

- 9 rescue and data gathering projects, all conducted during the month following the spill, including one detailed account of beachings and rescue operations
- 13 ecological monitoring projects, on medium and long term lethal effects, sublethal effects or both effects, certain projects lasting until 2000
- 2 restoration projects, which were restricted to measuring the survival rate of cleaned guillemots and a general review of restoration methods for bird populations after a spill.

Impact on marshes and mangroves

Coastal marshes (in particular maritime marshes) and their populations are prime victims of arrivals of floating pollutants, whether it be chronic pollution, such as solid waste, or exceptional pollution, such as oil spills. Mangrove swamps, exceptionally rich biotopes symbolic of intertidal marshes in the subtropical belt, are particularly sensitive to this type of pollution: the aerial roots of mangrove trees form a tangled web which is particularly difficult to clean and shelters a rich collection of fauna.

These biotopes belong to damp areas, in general regression due to the pressure of human activities. Their low hydrodynamism excludes practically all effects of natural clean-up. Their sensitivity to human intervention severely limits manual clean-up operations. Alternation of arrival and evacuation of water during the tidal cycle, the web of plants and the abundance of animal burrows promote, often significant, infiltration of pollutant into the sediment.

These biotopes therefore constitute high priority sites for **long term ecological monitoring of the qualitative parameters (specific diversity) and quantitative parameters (abundance and evolution of the pollutant, abundance of species, evolution biomass)**. Experience has shown that the effect of the oil itself rarely generates large-scale depopulation of the plant cover. These special cases can lead to the impact study suggesting localised restoration operations especially for mangroves where replantation can be carried out through nurseries.

The International Petroleum Industry Environmental Conservation Association report series on oil spills has dedicated two volumes to biological impacts of oil spills on saltmarshes and mangroves respectively. The document on saltmarshes explains the importance given to the subject by the fact that these marshes can trap and retain large quantities of oil and are difficult to clean. The mangroves report states that mangroves are well-known oil traps and that polluted mangrove trees often die, and claims that rehabilitation can be desirable for damaged areas of mangroves. It provides information on the techniques which can be used.

Impact on sea grass beds and coral reefs

Like coastal marshes and mangroves, coral reefs and phanerogam sea grass beds are biotopes symbolic of coastal environment conservation. The living part of coral reefs is located below the intertidal zone.

Marine phanerogam sea grass beds are largely subtidal. Both will not necessarily be victims of accidental marine pollution: slicks of floating pollutant which reach the shore in calm weather will not pollute the sea grass beds but only the parts of the coral nearest the surface. Smothering can be extensive in the case of a sinking pollutant or in the event of strong swell pushing the pollutant below the intertidal zone.

Ecological monitoring will include an assessment of mortality by direct contact with the pollutant, for the vegetation, sessile fauna and the associated mobile fauna.

However, the majority of the impact study on these biotopes will generally focus on the **toxic effects due to dissolved pollutant or pollutant in suspension in the water column: alterations in growth, reproduction and recolonising ability of flora and fauna and, for coral, modifications to mucus secretion**. If response operators attempt to reduce the floating pollutant's drift towards the shoreline by spreading dispersants on the slicks, an analysis of the overall environmental benefit or loss of these attempts may be added to the report, in order to provide experience feedback for use in future contingency plans.

The results will contribute to assessing the possibilities and advantages of carrying out a restoration operation on parts of the reef or the sea grass bed which are too damaged for complete, rapid natural regeneration.

Examples of restoration operations on sea grass beds after a spill are rare and generally experimental. Examples of restoration of coral reefs are, on the other hand, numerous. However, nearly all these operations involve repairing mechanical damage, due in particular to ships grounding, and not spills of pollutants. NOAA's Damage Assessment Remediation and Restoration Program website, previously mentioned on page 4, is an especially rich source of information on this subject.

Impact of response

During the first few days of spill response, the legitimate concern of reducing the possible impact on mobile species, able to move away from the polluted area, in particular birds, takes precedent over environmental protection. Part of response operations undeniably result in an ecological impact, as acknowledged in all impact reports. Training courses and manuals warn against the risks of excessive response. However, it is very difficult to ensure that these warnings are heeded in an emergency. There will therefore undoubtedly be impacts as a consequence of response to future spills, some as a result of excessive clean-up, others due to negligence.

Excessive clean-up, or "spotless" clean-up, involves removing all the pollutant, or at least all visible traces of pollutant, and in doing so running the risk of destroying parts of the flora and fauna which would have survived the presence of residual pollutant and would have acted as a source of natural repopulation.

Negligence consists of actions such as excessively driving over fragile ground or storing equipment or waste without taking adequate precautions, due to the apparent urgency of the situation.

Ecological monitoring will address the impact of response techniques point by point, by seeking to differentiate the damages caused by each of the two forms of clean-up impacts described above, using uncleaned areas as control sites. It should also clearly distinguish whether the techniques themselves were inappropriate or whether the damages resulted from careless implementation.

D4

The environmental impact study on the pollution from the *Sea Empress* oil spill in Wales began its report on the impacts of clean-up by praising the operational management which "*ensured that environmental and conservation considerations were given a high priority*". It then presented an interesting table showing the impacts of different clean-up techniques on 10 combinations of techniques and sites (see extract below).

Table 10.2 Observed consequences of clean-up activity carried out on rocky shores

Clean-up technique	Main study sites	Observed worst case effects
Dispersant spraying followed by scrubbing	Manorbier, Monkstone Beach.	Reduced densities of typical invertebrate populations compared with uncleaned areas. In particular there was a loss or failure of recruitment of iuvenile limpets at a Manorbier site where dispersants were used. In 1997 there was successful recruitment, so any effect was limited to one year. Loss of the lichen *Arthropyrenia halodytes* from barnacle cases. This was still evident in autumn 1997.
Dispersant spraying followed by scrubbing and high pressure washing.	Tenby (Paragon); St. Catherines Island; Gosker Rock.	Stripping of all invertebrates and algae, including surface biofilms, resulting in the delayed resettlement of algae and a different pattern of recolonisation by invertebrates, particularly barnacles and edible winkles. Limpet numbers remained low in Autumn 1997.
Wiping of rock with releasing agents	Manorbier, Skrinkle Haven, Church Doors	These agents were used only at points of public access where the biota was sparse. No effects due to cleaning were observed.

Use of resources

Natural resources used by humans are by no means excluded from ecological monitoring in the event of pollution: there is no fundamental difference in the effects of a pollutant according to whether a species is used as a resource or not. Ecological monitoring therefore takes into account species used as resources in the same way as all other species. For this, demographic models from the exploitation of these resources can be used, as well as models applicable to all types of populations.

However, the models used must be adapted to the specific use of the natural resources in question, this use being constantly altered from one location, technique, species and market to another, according to many fluctuating factors, of which a pollution incident is only one parameter amongst others. Ecological monitoring of these resources covers the qualitative and quantitative effects on these resources, without speculating on the damages suffered by economic operators, leaving this task to the economic operators themselves and economists.

Fishing resources

The first problem for fishing in the event of a spill is to establish the reality of the area and the products affected, to avoid any potentially dangerous products being put on the market and to prevent a loss of trust on behalf of consumers. The consumers, mostly located far from the affected areas, often see the situation as far more serious than it actually is, with the media focusing their images and texts on attention-grabbing information rather than taking an exhaustive approach.

Ecological monitoring during the emergency will therefore prioritise measuring the boundaries of the area affected and determining which species should be excluded from the market, and from which type of fishing. This monitoring will measure the increase and decrease in the level of contamination of species. It is also emergency monitoring that will confirm when the situation has returned to its original state or the tolerance level established by the standard in force. During this phase, ecological monitoring essentially provides information on health, whilst establishing the databases which will subsequently be required.

Once the critical stage is over, **long term ecological monitoring** of fishing resources, like for species not used as human resources, will take charge of quantifying the mortality rate induced in the short, medium and long term. It will qualify and quantify the sublethal effects on behaviour, growth and reproduction. It will monitor any increase in ulcers and necrosis, both internally and externally.

Both emergency and long term ecological monitoring of fishing resources are the subject of a wide range of literature. The literature establishes in particular that filter feeding molluscs, powerful bioaccumulators, are often more affected by organoleptic impact than seaweed, crustaceans and fish. It also states that impacts on mobile species, which can move away from the polluted area, are less serious and more difficult to prove than those on stationary species.

E1

Ecological monitoring of the contamination of fishing resources due to the Ievoli Sun *chemical spill.*

Ecological monitoring of the contamination of shellfish during the Erika *pollution.*

Aquaculture activities

E2

All aquaculture activities, both on land and at sea, require a supply of clean water. Shellfish feed on the phytoplankton resources available in this water and rely heavily on the natural environment for breeding. Aquaculture products have the same direct sensitivity to pollutants as comparable species which are not used as resources by humans. Such organisms, either attached to an elevated surface, on the seabed or in cages or basins, can only escape from a slick of pollutant by being removed from the affected area by human intervention. Any alteration of the water temperature or the natural balance of chemical compounds dissolved or in suspension by the pollution may cause damage to the aquaculture, by adjusting the water quality, by direct effect on the species bred, impact on plankton, or the effect on the capture of juveniles.

Ecological monitoring during the emergency will prioritise measuring the boundaries of the area affected and determining which products should be temporarily banned from sale, or even destroyed. It is also emergency monitoring that will determine, for species banned from sale, the progressive decrease in the level of pollution and will confirm when the situation has return to the tolerance level established by the standard in force. As for fishing, emergency ecological monitoring essentially provides information on health, whilst establishing the databases which will subsequently be required.

Once the critical stage is over, **long term ecological monitoring** of aquaculture resources, like for species not used as resources, will consist of quantifying the mortality rate induced in the short, medium and long term, as well as qualifying and quantifying the sublethal effects (on growth, resistance to epizootics, reproduction etc.). This particular type of ecological monitoring of aquaculture resources benefits from a wide range of literature on oil spills, however very little information is available on chemical spills.

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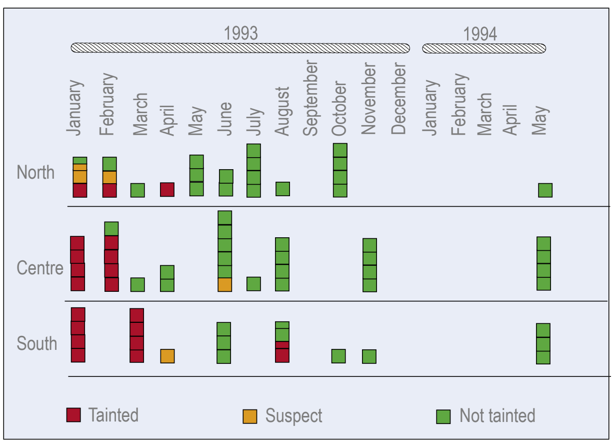
Emergency monitoring of shellfish farms by IFREMER during the Erika *pollution.*

Monitoring the tainting of farm-bred salmon as a result of the Braer *pollution in Shetland.*



Salt production and other water uses

Salt production uses a natural, non-biological resource from water: salt. Other activities, such as seaweed fertiliser production, make use of biological resources. These natural resources can be temporarily affected by pollution, either through smothering in oil (e.g. seaweed being covered in a sticky slick of heavy fuel oil), or by chemical alteration (e.g. bodies dissolved or in suspension liable to be trapped in the crystallisation of salt). Their exploitation may therefore be temporarily interrupted, until the situation returns to normal.

These impacts are usually very limited in space and time. However, they can make decision-making a difficult task. Opening salt production intakes to contaminated water may lead to the production of a product unsuitable for sale or which may harm the reputation of local salt production in the minds of the general public, a process which had previously been proud to display a strong image of natural production. The obvious solution would be not to open the water intakes based on the precautionary principle, however this is not necessarily deemed as reasonable for all those involved.

These issues are difficult cases for ecological monitoring leaders, who may be questioned on the results of these measures, and asked for predictions for the following months, in an exceptional situation, in which previous comparable cases are rare and poorly documented.

E3

In the case of the *Erika* oil spill (December 1999), the salt producers in Noirmoutier (France) decided to fill their salt pans in spring 2000, while those working in the Guérande deemed it necessary to sacrifice one year's production, although the water quality in the two areas was comparable. The Guérande salt producers had invested considerably more in the image of the produce over the previous years and knew of the presence of the nearby uncontrolled threat of buried oil slicks.

Makeshift dams built to protect channels feeding into salt pans from pollution.

Information output

Ecological monitoring of the impact of a spill comprises many different elements which must be gathered together, compared and organised to produce a final report, much anticipated by the authorities and the general public. It is therefore preferable if all the laboratories involved can publish their results within the same historical and geographical context. Furthermore, the information must be presented and discussed regularly as the study progresses during conferences open to the public. This means that the final report will be awaited more calmly, will be more reasoned and will benefit from greater credibility.

Historical and geographical management

On the international market, there currently exist archiving, modelling and decision-making software programmes capable of storing on a geographic information system all the data relating to a local or national pollution response contingency plan, of modelling slick drift and impact predictions, assisting in decision-making on the choice of response locations, techniques and means, receiving and managing all the information on economic and ecological consequences and quantifying economic and ecological damages. Many research and development centres also use information systems to store and process their environmental data.

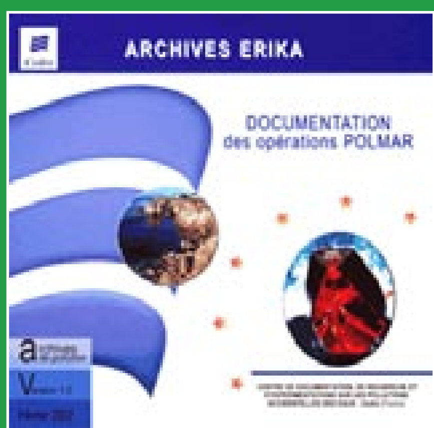
Using these systems for coordinated archiving and processing of sets of historical and geographical ecological monitoring data appears an attractive solution and several such trials have been carried out in the case of recent spills.

However, none of these trials has been completely successful, either because the systems used by the different teams involved were not sufficiently compatible, because the maps used were not sufficiently interchangeable, or because the data storage and formatting strategies were not sufficiently compatible.

The first example of pollution data management through a unique and complete geographic information system will necessarily come from a structure which has anticipated this in its contingency plan and its data archiving programme. In the meantime, **it will always be advantageous to agree on a choice of maps to be used by all parties involved and a common archive for the pollution and response operations**, whatever the means used.

F1

Based on work conducted for the Maritime and Coastguard Agency by a service provider in the aftermath of the *Sea Empress* oil spill in Wales (1996), *Cedre* embarked upon the construction of an archive on response operations for the *Erika* spill, the aim being for it to be as complete as possible, for use by any person needing to obtain this information, in particular teams in charge of ecological monitoring. This archive is available from *Cedre* on CD-Rom.



Permanent information flow

Complete and transparent communication has now become an indispensable element of response to an emergency situation, not only during the first few days of the crisis but also on subsequent controversial issues. Ecological monitoring of a pollution incident is no exception to this rule. **Journalists, the general public and politicians expect leaders to constantly provide accurate, comprehensible information on the progress of the monitoring work and the results obtained.**

This permanent information will inevitably take the form of the periodical publishing of printed documents. Well presented and illustrated information bulletins and concise progress reports are good ways of supplying information. If the release of the final report has to be delayed by a number of years, annual summaries of findings could be useful.

In the case of a major spill, a CD-Rom may need to be produced in order to gather a considerable mass of information in a reduced format. An example of the first instance of such a CD-Rom is presented below. An alternative may be to create a website to provide information on the monitoring work in progress. Such a website is a way of permanently making information available on the progress of each element. It could also refer readers to printed documents or updates of a CD-Rom for completed elements.

During the weeks following the pollution of the Spanish river Guadiamar by a spill of sludge from Aznalcollar tin mine (1998), the community of Andalusia created a website to provide information on the pollution and its impacts, which quickly became the reference for observers. The data on this website then acted as the basis for producing a CD-Rom in 2001, entitled "*Corredor verde del Guadiamar*", which presents the accident, its known impacts, the ecological monitoring programme and the rehabilitation programme in progress. The rehabilitation programme was based on the creation of a green belt along the banks of the river, over a large part of the area affected by the pollution.

Scientific symposiums

Scientific meetings and conferences are indispensable for presenting information on ecological monitoring. Such meetings can be divided into two categories: internal meetings with monitoring partners and open symposiums, in which the partners expose their results to external opinions.

Internal meetings gather together all the partners working on monitoring or, for major spills, a group of partners working on the same subject (e.g. impact on avifauna). These meetings not only serve the purpose of communicating the information gathered by partners to others, but they also help to coordinate and calibrate the work, in order to prevent incoherencies between the approaches of different teams. Organised as part of the monitoring programme, they can be restricted to only the programme partners, be open to selected external auditors, or open to the general public. In all cases, a report of the results should be made available to the public.

External symposiums are the opportunity for monitoring programme partners to compare their results with the results of other parties: firstly the international scientific community, as well as experts mobilised by the polluter in his defence. These symposiums can be organised as part of the monitoring programme, as a presentation of results prior to the publishing of the final report. Most often they consist of specialised sessions in periodical, well-known scientific conferences, ensuring freedom of expression of all points of view, within the limits of honesty and scientific objectivity.

The seminar "*Amoco Cadiz* – Consequences of an oil spill", held in Brest in November 1979, is an example of an external meeting organised by monitoring leaders, in the area where the pollution occurred and within quite a short time span, therefore in the presence of a highly sensitised audience.
The seminar "*Exxon Valdez Oil Spill - Fate and Effects in Alaskan Waters*" is an example of a special session organised within a wider context, that of a periodical conference (the 3rd session of the "*Symposium on Environmental Toxicology and Risk Assessment*", Atlanta, Georgia, April 1993), far from the polluted area and with a longer delay after the incident.

Final report

The final report is the closing document of the ecological monitoring programme. It objectively summarises the work conducted and the results obtained, highlighting the points of convergence as well as any points of divergence, in clear, comprehensible terms. It qualifies and quantifies the impacts, eliminating all possible controversies by its clarity and objectivity.

It describes how and to what extent natural balances have recovered naturally or through human intervention. It outlines ecological lessons to be learnt from the pollution and from the actions taken, providing all concerned parties with directly applicable feedback to help improve preparedness for future incidents. It should not enter into all the details of the operations conducted and the hypotheses examined and rejected. However, it should provide a complete list of the monitoring work carried out and the reports published.

It need not go beyond purely factual conclusions. However, it is generally beneficial to complement these hard facts with recommendations on protecting sites and populations, assessing the situation when the spill occurs, the most environmentally friendly response techniques, and any other important points for response decision-makers or ecological monitoring organisers.

There is not always a national committee in charge of establishing the environmental impact of a pollution incident, even in the case of a major spill. Thus there was no final report by such a committee for the *Amoco Cadiz* spill (1978) in Brittany, nor for the *Exxon Valdez* spill (1989) in Alaska. For the *Amoco Cadiz* pollution, the information is mainly available through the texts published in 1981 from the 1979 seminar "*Amoco Cadiz* – Consequences of an oil spill", and in a summarised form, in the scientific and technical CNEXO report on this seminar, also published in 1981. For the *Exxon Valdez*, two main sources exist: firstly, the texts from the 1993 seminar "*Exxon Valdez* Oil Spill: fate and effects in Alaskan waters", published in 1995, and secondly the articles published in the various biannual sessions of the International Oil Spill Conference following the spill.

The final environmental impact report on the *Sea Empress* pollution in Wales (1996) closes with two categories of logical recommendations in a report which was designed both to be complete and delivered in a relatively short time span after the accident (2 years). The first category consists of specific recommendations for this pollution and the affected area, dealing mainly with monitoring work to be continued on the sites and populations for which no full report was able to be established. The second category involved recommendations of general interest, based on the experience of this pollution, to be used by the different government agencies and departments on the research and actions liable to improve the management of future incidents.

Post-report stage

Although the final report may bring an end to the ecological contributors' mission, that of the leaders still continues, sometimes for several years, on two particular points: the interface with post-spill scientific studies and compensation of scientific monitoring.

It is exceptional for the final impact report not to highlight a number of points for which **longer studies deserve to be undertaken to clarify the medium and long term impacts**, without necessarily justifying keeping an overall scientific monitoring programme going. These longer tasks generally focus on hypothetical impacts and require scientific knowledge which is still incomplete. They naturally fit into the framework of scientific post-pollution studies, designed to increase knowledge to improve management of future pollution incidents. Ecological monitoring leaders could therefore be asked to contribute to defining these studies, to ensure that they are well adapted to the needs identified through ecological monitoring.

These studies are designed to improve preparedness for subsequent pollution incidents and are naturally not covered by compensation due from the source of the pollution of the liable party. **Ecological monitoring is, on the other hand, able to be covered by this compensation.** This is of course the case in countries which allow for the compensation of ecological damages. However, it is also the case in the countries which have prioritised environmental restoration, such as France: decision-making on this restoration can only be based on appropriate ecological monitoring. The difficulty is understandably in agreeing on the extent and cost of what is deemed appropriate. Leaders will be obliged, sometimes after many years, to explain and justify the actions undertaken.

In a document published in February 2001 for the 1992 IOPC Funds intersessional working group on the acceptability of claims for environmental damages, ITOPF differentiates three types of ecological monitoring studies:

- Specific studies connected to the possible restoration of affected habitats and populations, or to the assessment of long term effects on populations used as resources
- Integrated physical, chemical and biological studies, designed to assess the overall impact of the pollution on different parts of the marine environment
- Studies on particular aspects of pollution response, involving unusual pollutants or new response techniques, liable to improve the efficiency of response to future spills.

According to ITOPF, only the first two types of studies may be compensated.

More information

The documents listed here are only the basic works to which reference may be made.
Many other documents may be of use.
Many are available from *Cedre*'s documentation centre.

■ Impact reports

MARCHAND M. Amoco Cadiz : bilan du colloque sur les conséquences d'une pollution accidentelle par hydrocarbures. Brest: 1981. 86 p. (Rapport scientifique et technique CNEXO n° 44).

ECOLOGICAL STEERING GROUP ON THE OIL SPILL IN THE SHETLAND. The Environmental Impact of the Wreck of the Braer: final report. Edinburgh: The Scottish Office, 1994. 207 p.

Seguimiento de la contaminacion producida por el buque Aegean Sea. Madrid: Ministerio de Medio Ambiente: 1996. 185 p.

SEA EMPRESS ENVIRONMENTAL EVALUATION COMMITTEE. The environmental impact of the Sea Empress Oil Spill: final report of the SEEEC. London: The Stationery Office, 1998. 135 p.

■ Proceedings of symposiums

Amoco Cadiz : conséquences d'une pollution accidentelle par les hydrocarbures. Actes du colloque international, Centre Océanologique de Bretagne : Brest (France), 19-22 November 1979. Paris: CNEXO, 1981. 881 p.

WELLS P.G., BUTLER J.N., HUGUES J.S. Exxon Valdez Oil Spill: fate and effects in Alaskan waters. Papers presented at the Third Symposium on Environmental Toxicology and Risk Assessment, Atlanta (Georgia), 26-28 April 1993. Philadelphia: American Society for Testing and Materials, 1995. 995 p. (Special publication, 1219).

DAVIES J.M., TOPPING G. The impact of an oil spill in turbulent waters: the Braer. Proceedings of a symposium, the Royal Society of Edinburgh, 7 - 8 September 1995. London: the Stationery Office, 1997. 263 p.

■ CD-ROMs

Corredor verde del Guadiamar : un espacio para todos. (2001). [CD-ROM]. Sevilla (Andalusia): Junta de Andalucia, Consejeria de Medio Ambiente. 1 CD-ROM.

2001 International Oil Spill Conference: global strategies for prevention, preparedness, response and restoration. Abstracts since 1969 and full text. Proceedings for 2001, 1999, 1997, 1995. (2001). [CD-ROM] Tampa (Florida): Tampa Convention Center. 2 CD-ROMs.

■ Websites

National Oceanic and Atmospheric Administration (NOAA). Damage Assessment, Remediation, and Restoration Program (DARRP). (Page visited on 7 January 2002). DARRP sites, [online]. Web address: www.darrp.noaa.gov.

■ Guides on the impact of pollutants

International Petroleum Industry Environmental Conservation Association.

Guidelines on biological impacts of oil pollution. 1990. 15p. London: IPIECA report series, vol. 1.

Biological impacts of oil pollution , London: IPIECA report series:

- coral reefs, 1992. 16p.: vol. 3
- mangroves, 1993. 20p., vol. 4
- saltmarshes, 1994. 20p., vol. 6
- rocky shores, 1995. 20p., vol.7
- fisheries, 1997. 28p., vol. 8
- sedimentary shores, 1999. 20p., vol. 9.

■ Reference work on the effects of oil

Oil in the sea: inputs, fates and effects. Washington, (USA): National Academies Press, 1985. 601p.

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