ENVIRONMENTAL CONSIDERATIONS IN SHORELINE RESPONSE

Jenifer M Baker
Shrewsbury, UK

ABSTRACT

Oil spill response aims to minimize environmental damage (taking into account both ecological and socioeconomic points of view), and to reduce the time for recovery by achieving an acceptable standard of cleanliness. For shorelines, this may involve both actions at sea and actions on the shore. At-sea response tackles slicks floating towards shorelines. Possible approaches include guiding or redistributing the oil into less sensitive environmental components, e.g. dispersing oil into the water column so that it does not reach the shore, or deflecting oil away from marshes onto a sandy beach. Actions on the shore include protecting sensitive areas by shoreline booming, removing oil from the area of concern and disposing of it, or deciding to rely entirely on natural cleaning processes.

Initiation of a response, or decision to stop cleaning or leave an area for natural clean-up, should be based on evaluation which has taken place both before the spill (as part of the contingency planning process) and after the spill. This evaluation includes both sensitivity mapping and net environmental benefit analysis, i.e. the advantages and disadvantages of different responses need to be weighed up and compared both with each other and with the advantages and disadvantages of natural clean-up. Natural cleaning timescales can range from less than one year to more than 30 years and are determined by many factors notably shore energy levels, with cleaning being faster on exposed (mainly rocky) shores than on sheltered shores. The evaluation process also requires taking into account the particular circumstances of the spill (e.g. oil type and weather conditions), and the practicalities of clean-up response.

For a full environmental perspective it is necessary to consider both the shore in itself, and any systems which interact with the shore in some way, e.g. bird colonies with birds sometimes feeding on the shore, or nearshore shellfish beds which receive shore run-off. Interacting systems may also include disposal systems which receive oil cleaned from the shore.

INTRODUCTION

Since the first major tanker accident (the *Torrey Canyon* in 1967), a great deal of work has taken place to assess the effects of oil spills and various clean-up techniques, and to monitor ecosystem recovery rates. This experience (which has been distilled in the IPIECA Report Series - see References section) is a great help in predicting possible outcomes in new situations. Such prediction is an essential part of the net environmental benefit analysis (NEBA) approach to spill response, in which the predicted advantages and disadvantages of response options are weighed up and compared both with each other and with the advantages and disadvantages of natural clean-up. It is appropriate that in the Millennium Year, the report on *Choosing Spill Response Options to Minimize Damage* (IPIECA 2000) draws upon the lessons of the past to advocate the NEBA approach for the future. It is this approach that is used in the present paper.

AT-SEA RESPONSE OPTIONS FOR SHORELINE PROTECTION

Shoreline protection should be a consideration during the earliest stages of an oil spill. Even if the spill occurs many miles offshore and it is not clear where the oil will move, a wide-ranging preliminary evaluation is an appropriate precaution, taking into account the most important shoreline resources in all the possible directions that the slicks may travel. If monitoring of the slick indicates that it is likely to move onto sensitive shores, it has to be decided if and how it can be treated while it is still well offshore (at the same time taking action to protect priority shore areas by coastal booming).

If the oil is approaching the shore and trajectories have been predicted, evaluation should focus on a particular area in more detail, for example using information from local sensitivity maps (IMO/IPIECA 1996). It may be possible at this stage to plan deflective booming, whereby oil is guided away from sensitive shoreline areas onto 'sacrificial beaches'. Typically, these are easily cleaned beaches of low biological productivity, such as the ESI 3 beaches mentioned in the next section. Rapid decision making is particularly important for nearshore situations, where there may be only a few hours available for at-sea response before the oil reaches the shore.

The main response options for oil slicks on water are physical removal by containment and recovery, dispersant spraying, or reliance on natural processes. *In-situ* burning may be an option in some cases (particularly in ice-infested waters). The physical removal of oil from the water surface reduces the threat to shorelines (and also aquatic birds and mammals). However, in terms of efficiency, containment and recovery are limited by strong waves and currents. Recovering 10 per cent of the oil at a large spill in the open sea is considered good for these mechanisms.

Dispersants, by helping to break up a surface slick, can also help to protect shorelines, birds and mammals - but the dispersed oil enters the water column where it may increase the threat to organisms such as fish larvae (IPIECA 1993b), or the risk of tainting of shellfish and fish held in cages. Dispersants can be used under sea conditions where mechanical collection is impossible and have been effective on some spills (IPIECA 1993b, Lunel and Elliott 1998). However, they need to be used quickly (typically within one or two days) before the oil becomes too weathered or emulsified. Moreover, they are less effective on the heaviest oil types (e.g. the heavy fuel oil lost from the *Erika*, 1999). If sensitive shorelines are under imminent threat from floating oil slicks and when it is agreed that fisheries interests are at low risk, then dispersant spraying can have a net environmental benefit in some cases (see IPIECA 1993b for examples of scenarios).

Consideration of cleaning by natural processes needs to take natural cleaning timescales into account. These can be expressed in 'half-lives' (the time taken for natural removal of 50 per cent of the oil from the water surface). These typically range from about half a day for the lightest (Group I) oils such as kerosene to seven days or more for the heaviest (Group IV) oils such as heavy fuel oil (ITOPF 1987). It follows that with spills well out to sea, light oils may dissipate through natural processes before reaching any shoreline, whereas heavy oils may travel for many days and eventually reach shorelines considerable distances from the spill site.

SHORELINE SENSITIVITY, AND PRIORITIES FOR PROTECTION

Different types of shoreline may be ranked using the basic principles that sensitivity to oil increases with: increasing shelter of the shore from wave action; penetration of oil into the sediments; natural oil retention times on the shore; and biological productivity of shore organisms. Many sensitivity maps classify shorelines using a vulnerability or environmental sensitivity index (ESI), typically based on the original 10-point index of Gundlach and Hayes (1978). Natural cleaning and recovery times are generally rapid on exposed rocky headlands (ESI 1) and exposed wave-cut platforms (ESI 2). Oil does not penetrate readily into gently sloping fine-grained sand beaches (ESI 3), thus facilitating mechanical removal. Oil penetration may be deeper, and clean-up more difficult, in more steeply sloping shores of medium to coarse grained sand (ESI 4). ESI 5 beaches are of mixed sand and coarser sediments, and ESI 6 includes a range of gravel, pebble and boulder beaches with high permeability. There is often significant biomass on ESI 7 tidal flats, and ESI 8 sheltered rocky shores. Sheltered tidal flats (ESI 9) are very productive, and the greatest biological productivity is typically found on ESI 10 shores (saltmarshes and mangroves). The extreme shelter of such areas means that they act as oil traps, often with severe consequences for the flora and fauna.

An ESI is a convenient way of summarizing information about inherent shore characteristics, however the index numbers do not represent fully quantified sensitivity, for example ESI 5 is not necessarily five times as sensitive as ESI 1. Moreover, ESI ranking gives only part of the picture because it does not take into account uses of the shore by wildlife and people. For example, a sandy shore rated as ESI 3 (relatively low sensitivity) might be important for tourists, or for turtle egg laying, at certain times of year. Thus for any particular spill, the ESI numbers do not necessarily indicate the priorities for protection, which may change seasonally.

Human use features of shorelines include fisheries resources (e.g. shellfish beds and fish traps) and other features such as harbours, marinas and slipways; industrial water intakes; amenity beaches; sites of cultural or historical significance; and park areas. Sensitivities are influenced by many factors including ease of protection and clean-up, recovery times, importance for subsistence, economic value and seasonal changes in use. The sensitivity of coastal parks is high because these areas are likely to contain sensitive resources such as birds and mammals; and some parks are an attraction for 'ecotourists'.

For any particular area, priorities for protection are ideally decided before a spill happens as part of the contingency planning process, and indicated on sensitivity maps (IMO/IPIECA 1996). Decision-making should be consultative, involving all interested parties such as those representing wildlife, fisheries and tourism. Contingency planning should also address the practical questions of how protective booms will be procured and deployed, including access and shoreline fixing points.

SHORELINE CLEANING OPTIONS

The first option to consider should be natural clean-up. Observed timescales range from a few days (some case histories for very wave-exposed rocky shores) to more than 30 years (a few case histories involving unusually thick deposits of oil on very sheltered marshes). In many cases there is good natural cleaning with recovery well underway within one to two years (Baker 1997). As cleanup operations have the potential to cause some adverse effects, the natural clean-up option is often the best. Intervention may be considered necessary in cases where:

- 'free' or 'bulk' oil is present on the shore, such that it may spread with tidal action and contaminate a wider area, or smother plants and animals. In such a case decision making is straightforward because it is usually obvious that rapid removal of the oil (e.g. using vacuum pumping) will reduce the area or extent of damage;

- the predicted length of the natural cleaning time is unacceptably long to the main stakeholders. For example, six weeks natural cleaning time for an amenity sand beach may be unacceptably long if a spill occurs just a few days before the main tourist season. Disruption caused by clean-up (e.g. removal of shore material and associated organisms) may be justified if this will restore an important human use of the shore. Conversely, longer natural cleaning times may be acceptable if the main interest is, for example, plants and animals on a remote shore in a conservation area;

- it is predicted that interacting systems will be adversely affected (see subsequent section on wider considerations of environmental benefit).

Clean-up methods can be classified into non-aggressive and aggressive. Non-aggressive shore cleaning (methods which have been shown to have minimal impact on shore structure and shore organisms) include:

- vacuum removal of pooled oil;

- physical removal of surface oil from firm sandy beaches using machinery such as front-end loaders (avoiding the vehicles mixing the oil into the sand, and the removal of underlying sediment);

- manual removal of oil, asphalt patches, tar balls etc., by small, trained crews;

- collection of oil using sorbent materials (followed by safe disposal);
- low-pressure flushing with ambient temperature seawater; and
- bioremediation using fertilizers to stimulate indigenous oil-degrading bacteria.

In appropriate circumstances these methods can be effective, but they also may be labour-intensive and clean-up crews must be careful to minimize damage by the wheels of heavy vehicles and trampling by many human feet. Such damage is particularly likely on ESI 10 shores (see above), so the least damaging option for oiled marshes may be to leave them to recover naturally, even if this takes some years. The methods do not work well in all circumstances. For example, low pressure flushing is ineffective on weathered, firmly-adhering oil on rocks; and bioremediation is ineffective for sub-surface oil in poorly aerated sediments.

Aggressive methods of shore cleaning (those that are likely to damage shore structure and/or shore organisms at least in the short term) include:

- sediment relocation, i.e. moving sand or coarser sediments down the beach where they receive greater natural cleaning by wave action;
- removal of shore material such as sand, stones, or oily vegetation together with underlying roots and mud. (In some cases the material may be washed and returned to the shore);
- water flushing at high pressure and/or high temperature;
- sand blasting; and
- chemical cleaning.

Aggressive clean-up may be considered justifiable in some cases, for example if sticky viscous fuel oil is adhering to rocks which are soon to be used by seals during the breeding season (as described below in the section on wider considerations of environmental benefit). However, it needs to be borne in mind that aggressive clean-up can prolong recovery times. For example, following the 1978 *Amoco Cadiz* spill in Brittany, some areas of marsh were cleaned using heavy equipment. As much as 50 cm of sediment was removed and subsequently it was realized that some of the marsh surface was lowered to the extent that it was at the wrong intertidal height for plant growth, and this delayed recovery (IPIECA 1994).

WIDER CONSIDERATIONS OF ENVIRONMENTAL BENEFIT

Consider the example given above, of fuel oil adhering to rocks at a seal breeding site. If effective removal of the oil can only be achieved by high-pressure hot-water washing or sand blasting, prolonged recovery times of shore organisms (i.e. organisms such as molluscs and algae which live on the shore) might be accepted because the seals are given a higher priority. The seals are an example of what have been called interacting systems (IPIECA 2000), which impinge on or use or are related to the shore in some way, but are not generally regarded as permanent shore features. Other examples of interacting systems are:

- bird colonies, with birds nesting above the intertidal zone but sometimes visiting the intertidal zone; or feeding in nearshore water which may receive oily run-off from a polluted shore;
- nearshore habitats such as coral reefs, seagrass beds, and kelp beds, which may receive oily run-off or oil and sediment mixtures from a polluted shore;
- socio-economic features such as nearshore shellfish beds or fish breeding areas.

If non-aggressive cleaning of the shore is carried out for the sake of interacting systems, this can be done in most cases without a significant adverse effect on the longer-term recovery rates of shore organisms (Sell *et al.* 1995).

With aggressive cleaning, it will be necessary to assess the relative importance and likely recovery rates of the interacting systems on the one hand and the shore organisms on the other. One consideration here is that populations of wildlife species (mammals and birds) are likely to be smaller, more localized, and slower to recover if affected by oil than populations of abundant and widespread shore organisms such as algae, barnacles and mussels.

Another consideration is that socio-economic issues may be of such importance that they dictate clean-up. For example, consider a cobble shore with sub-surface oil which is gradually leaching into the nearshore waters. Near the shore on the shallow sea bed are abundant shellfish which are collected for food by local people. Ecological recovery on the shore has started without any clean-up but the shellfish are tainted. It is predicted that some tainting will continue for several years because of chronic leaching from the shore, making the shellfish inedible for this period of time. Does this justify aggressive removal of the oil? From an ecological point of view, there is no justification, because the recovery of the shore would be set back. Moreover, it is doubtful that there would be any ecological benefit to the shellfish populations, which can survive even though they are tainted. There might, however, be local consensus that compelling economic benefits of cleanup take precedence over the ecological point of view.

Finally, it is also necessary to consider possible adverse effects on systems which may receive oil cleaned from the shore. For example oil may be buried in sand dunes near the shore as a temporary or long-term disposal method - in such cases some secondary damage is likely, for example disturbance to soil caused by vehicles transporting the oil, or effects on sand dune vegetation. In some such cases, there is the possibility that overall environmental damage will be less if the oil remains on the shore, either for entirely natural cleanup or for interventions (e.g. bioremediation, tilling) which do not involve collecting and transporting the oil to other sites.

It is concluded that the NEBA process should include the weighing up of environmental advantages and disadvantages of disposal methods as well as the advantages and disadvantages of clean-up options on the shore. Using natural cleaning processes on the shore as far as possible minimizes the possibility of secondary damage resulting from clean-up interventions and disposal.

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