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Viewpoint

The principles of effective post-spill environmental monitoring in marine environments and their application to preparedness assessment

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ABSTRACT

Understanding the fate and effects of marine spills is essential if the scientific and response communities are to develop best practices. The effective deployment of environmental monitoring activity can be complex and requires planning and coordination but the levels of preparedness to deliver the necessary expertise, coordination and funding are often low. This paper identifies and describes the importance of 8 principles of effective post-spill monitoring programmes. These principles are then used in the assessment of monitoring preparedness through the generation of a monitoring preparedness assessment score (MPAS). This approach can be used by local, regional or national authorities to establish the level of preparedness for environmental monitoring and prioritise areas for improvement. It also has value to responders, policy makers, environmental scientists and planners as a tool to assess preparedness and capability for specific scenarios. The approach is demonstrated through the assessment of previous incidents and potential future scenarios.

1. Introduction

Most authorities, backed up by statistical data, generally agree that major spills of oil and chemicals into the marine environment are historically in decline (e.g. Schmidt-Etkin, 2011). A recent review (Musk, 2012) provides compelling evidence of the improvements made in terms of volumes of oil spilled from tanker incidents over the past decades despite a steady increase in oil transported by sea (Purnell, 2009). Equivalent global statistics for spills from the offshore oil and gas industry are more difficult to source but data, for example in the USA (Anderson et al., 2012), also indicate improvements over recent decades. This positive trend was brought to a decisive end as a result of the Macondo spill in 2010 but this could be viewed as an exceptional incident and that the underlying trend in terms of spills is one of improvement.

The situation for spills of chemicals, more commonly referred to by responders as hazardous and noxious substances (HNS), is less well defined in comparison to incidents involving oil but, with international marine transport of a wide range of chemicals (Radović et al., 2012; Neuparth et al., 2012), the risk of HNS spills occurring is potentially ever present. It remains inevitable, however, that major marine spills will occur, with their associated environmental impacts and even modest spills can have major environmental consequences if the receiving environment is particularly sensitive.

In general, however, the marine environment has a substantial capacity to assimilate contaminants without major impacts and can demonstrate a high resilience through recolonisation and recovery. However, Kirby and Law (2010) list several marine accidents where the marine impacts were measurable, significant and, in some cases, long-term. Therefore, in addition to effective national and regional procedures for search and rescue, salvage and counter pollution, there is also a need to ensure that procedures for the implementation of effective post-spill monitoring and impact assessment are in place. Kirby and Law (2010) set out the key reasons why this was necessary;

- *Primary impact:* the need to provide early evidence of potential environmental and economic impact to key stakeholders, e.g. government and the general public.
- *Wider effects:* the need to apply an appropriate and effective method of investigating the impact on the wider marine environment and its resources.
- *Best methods:* impact assessment methodology needs to be considered that not only assesses the short-term impacts, but also allows the prediction of potential longer-term impacts.

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- *Efficient resource use:* the need to ensure effective use of resources during monitoring so that unnecessary procedures are avoided but that potentially useful ones are not overlooked.
- *Mitigation effectiveness:* the need to provide an assessment of the effectiveness of spill response and clean-up activities, including the use of dispersants.
- *Compensation/liability:* the need to provide monitoring and assessment input to the determination of compensation and/or liability issues as necessary.

There are three core elements that constitute a fully effective post-incident monitoring capability; (i) science quality, (ii) coordination and organisation, and (iii) preparedness and responsiveness. If any one of these is missing or sub-standard then the ultimate programme and the information it produces may be flawed and the overall effectiveness compromised.

The conduct of post-incident marine monitoring involves the practical application of scientific process and technique under potentially difficult and unforeseen circumstances with short notice and tight delivery deadlines. Understanding what scientific methods are necessary, how they are best applied in situ and having access to appropriately skilled scientists is clearly a pre-requisite of any scientifically robust monitoring system. However, the circumstances of marine spills can be extremely complex, potentially involving the measurement of several hazardous components and a need to assess impacts in many receiving environments and at multiple trophic levels. Therefore, coordination of the response and the management of logistics, financial aspects, communications and reporting can be equally as important as the science. Finally, although marine emergencies occur without warning, there is still a need to be able to initiate monitoring activity in a timely manner, especially if there is an opportunity to collect samples to inform a baseline dataset before an area is impacted. This essential element of responsiveness is often overlooked and has resulted in delays of days, weeks or even months for monitoring programmes to be fully in place (Kirby and Law, 2010) in the absence of a preparedness strategy.

The improvement of post-spill monitoring and impact assessment, through the consideration of these core elements, is the ongoing subject of a cross-government programme in the United Kingdom called Premiam (Pollution Response in Emergencies: Marine Impact Assessment and Monitoring, see www.cefas.defra.gov.uk/premiam). This programme was initiated in 2009 and has involved a partnership of 22 UK government departments and agencies with an interest in the effective conduct of post-spill monitoring. Over this time a number of improvements have been made to national preparedness and a number of principles associated with an effective monitoring programme have emerged. These 8 principles are;

1. Scientific guidance.
2. Skills and knowledge.
3. Equipment.
4. Funding.
5. Responsibility and management.
6. Integration and coordination.
7. Support and buy-in.
8. Practice.

This paper will explain each of the principles and review how they are being addressed through a national case study (United Kingdom). Finally, a 'monitoring preparedness assessment' approach is introduced and demonstrated using the 8 principles at its core. The method can be used to generate a monitoring preparedness assessment score (MPAS) that can be a useful tool in establishing the level of preparedness at national, regional or local levels, for different types of incidents and emergency scenarios, and to indicate the specific areas for improvement.

2. The principles

2.1. Scientific guidance

Any effective environmental monitoring programme needs to be underpinned by strong scientific principles. The selection of the most effective survey approaches, analytical methods and data analysis/interpretation is essential if a programme is to be scientifically robust and stand up to later scrutiny and peer review. An in-depth understanding of post-incident monitoring methodologies is needed to develop a programme of the necessary scientific quality. The time for developing the overarching scientific principles and guidance for an environmental monitoring programme is not in the immediate aftermath of an incident.

Key areas which any guidance needs to consider include:

- Clear definitions of a programme and what it needs to achieve.
- Survey design.
- Sampling strategies and methods.
- Chain of custody, labelling, transport and storage.
- Chemical analytical methods.
- Ecological impact assessment method (for key environments and trophic levels).
- Ecotoxicological assessments.
- Quality control.
- Potential implications for human health.

Every incident is unique and requires a tailored approach to monitoring, building on a sound scientific approach such as that advocated within the Premiam guidelines (Law et al., 2011). The adopted approach should also allow for more specific, innovative and opportunistic techniques to be incorporated into the programme as necessary. Indeed sub-guides allowing for more prescriptive approaches for spill scenarios with specific chemicals or in designated areas might also be effective supplements to the overarching guidance. The scientific guidance might also provide advice on the use of oil/chemical spill trajectory modelling and sources of information on the physical characteristics of chemicals transported by sea (GESAMP, 2011; IMO, 2011) both of which can be important sources of information in the development of sampling strategies.

2.2. Skills and knowledge

The availability of scientific guidance is considered essential but the benefits it provides can only be realised if personnel and organisations with the necessary skills and knowledge are available to implement them. Skills required might include; survey managers, chemists, ecotoxicologists, marine ecologists (of several types), fisheries scientists, oceanographers and modellers. In addition to these scientific disciplines, individuals with other key skills, such as navigation, equipment deployment/maintenance, communications and project management will be equally important.

None of these skills are unique to post-spill monitoring so many will be found in individuals and organisations undertaking similar tasks for different purposes. They need to be identified and engaged as part of the preparedness strategy. Assessing the availability of key skills and knowledge is recommended so that gaps can be assessed and any necessary upskilling or training activities identified and implemented.

2.3. Equipment

No effective monitoring programme can be implemented without the availability of and access to the necessary equipment. The general types of equipment required should be identified in the guidance, but the required equipment resources will clearly vary substantially depending on the complexity of the incident, size of spill and the location. Nevertheless, even for the smallest incidents some common equipment types are likely including; sample bottles/containers, water/sediment samplers, labelling equipment, storage facilities (e.g. fridges/freezers etc.) and these will need to be clean and available at very short notice. More complex or larger incidents may require consequently more sophisticated sampling and survey equipment and the availability of state of the art research vessels from which to deploy them. Examples include the use of towed or autonomous in situ sensors (e.g. for measuring hydrocarbon concentrations by fluorimetry (Hurford et al., 1989; Brown, 2000)) or the deployment of photographic or video surveillance and acoustic technology (Hu et al., 2008; Jha et al., 2008; Leifer et al., 2012; Eriksen, 2013). In addition to sampling and survey equipment and the availability of vessel platforms from which to deploy them, appropriate provision needs to be made for the storage and transport of water, sediment and biota samples which, for large incidents, can present a significant logistical challenge.

It is recommended that an inventory of equipment and facilities resources is developed and maintained. This should also consider the availability of specialist analytical capability (e.g. analytical chemistry, ecotoxicology, and ecology/taxonomic laboratory facilities) which might be available from government, academic or commercial providers.

For particularly high risk areas, some consideration could be given to the provision of a pre-prepared stockpile of sampling and monitoring equipment but, in reality, this is unlikely to be a solution for most incidents. However, consideration does need to be given as to where equipment is hosted in relation to high risk areas as significant delays due to commissioning and transport can compromise the necessary prompt initiation of monitoring activities.

2.4. Funding

It is a fact that once scientists are engaged or equipment deployed as part of an environmental monitoring programme a monetary cost is being incurred. The necessary skills and knowledge required for marine monitoring generally reside in highly trained and experienced personnel and some of the equipment and facilities are expensive to develop and maintain. For example, the chartering of vessels from which to conduct monitoring activities can be especially costly. Therefore, it is strongly recommended that a source of funding for the initiation of monitoring activity is agreed and made available in advance as part of a preparedness strategy. The provision of an effective monitoring programme must, though, also encompass cost-effectiveness in its design.

Sources of funding will vary depending on where the incident occurs but are likely to be from;

- Government (national, regional or local).
- The polluter (under the 'polluter pays principle').
- Compensation funds.

However, while the 'polluter pays principle' is fair and should be pursued with all vigour, neither this nor any compensation route is likely to result in funds being made available promptly enough for the initiation of monitoring. Therefore, it is recommended that relevant government departments and agencies consider where the responsibility lies for funding and put in place an appropriate mechanism for making this available as soon as monitoring is considered necessary. The need for an agreed up-front funding source should only be necessary for the first few days of activity after which more considered discussions about ongoing funding can take place.

2.5. Responsibility and management

Another potential source of delay in the first few hours and days of an incident is uncertainty over who is responsible for initiating monitoring activity and the development of a coordinated monitoring strategy. It is recommended that the decision making for monitoring initiation and overall management and coordination of the response lies with a lead authority and that a highly experienced individual leads the monitoring effort.

2.6. Integration and coordination

A fully efficient monitoring programme will be characterised by effective integration and coordination of relevant activities from a range of sources. In most cases, the core effort will primarily be delivered by government departments/agencies but this could still involve several organisations. This is especially the case where responsibilities for different 'at threat' resources and zones are not addressed by one body. For example, monitoring may be required to assess impacts associated with fisheries, environmental/conservation issues or human health (from food and/or leisure exposure) in both coastal and/or offshore environments.

While core government bodies with statutory responsibilities will likely lead any monitoring response it is recommended that other relevant activities are also incorporated into the monitoring programme. Other sources of monitoring activity might include:

- Routine sampling as part of national or regional environmental quality monitoring (these can be an important source of baseline information).
- Academic studies; universities will often use real incidents as an ideal opportunity to deploy developmental techniques if funding is available.
- Industry/commercial; if the 'polluter' is identified they may well initiate monitoring activities of their own.
- Voluntary/public activities; local and national groups such as wildlife and conservation associations can provide an important source of local knowledge and may well instigate their own monitoring activities.

It is recommended that efforts are made to integrate these alternative sources of monitoring information into the overall programme.

2.7. Support and buy-in

The previous two principles have considered issues of responsibility, leadership, integration and coordination. Essential as these are, they tend to relate to those bodies directly involved with monitoring activity or with statutory/policy responsibility for such. However, in the event of a large or complex incident the number of interested stakeholders can be much broader. These might include other government bodies, industry bodies, conservation groups, local interest groups and, potentially, the public. Effective communication of the results of monitoring to these groups is paramount.

2.8 Practice

The final principle relates to ensuring that any practical, scientific, management and communications processes implemented as part of a pre-planned response to environmental monitoring are robust and proven to work. However much planning and guidance is available there is no substitute for practicing the response through exercises. Response activities such as search and rescue, spill treatment and clean-up and communications (including access to expert scientific advice sources) are generally well rehearsed via a range of local, regional and national (sometimes trans-national) emergency exercises. However, the coordination required to conduct environmental monitoring activities which may include the deployment or engagement of several teams (e.g. sampling, analytical, modelling, ecological impact assessment) may also be highly complex and challenging. This is rarely, if ever, exercised and so confidence that initiation of monitoring will run effectively is lacking. Ideally, the deployment and management of environmental monitoring should also be practised within response exercises, so that capability can be assessed and that improvements can be made via feedback and review.

3. National case study – the United Kingdom

The principles of effective monitoring programmes have been outlined above. In this section a case-study is provided that describes how these challenges are being addressed in the United Kingdom within Premiam (http://www.cefas.defra.gov.uk/premiam).

3.1. Scientific guidance

It is recognised that every marine spill incident will represent a unique combination of type of spilled material, volumes/combinations of material, geographic location, resources at risk, seasonal sensitivities and prevailing weather conditions. As such, tightly prescriptive monitoring guidance is neither possible nor practical. Guidance on the design and operation of monitoring programmes has been published (Law et al., 2011). The scientific credibility of the guidelines is underpinned through an experienced group of authors and a comprehensive programme of consultation with all key stakeholder groups in advance of publication.

3.2. Skills and knowledge

The conduct of a potentially complex monitoring programme will need access to expertise from a range of disciplines. The UK is generally well supplied with these skills across a range of organisations, following post-incident monitoring of a number of significant marine incidents (e.g. the *Braer* and *Sea Empress* oil spills, the *MSC Napoli* grounding) in UK waters over the last 20 years. However, identifying and engaging with this community can still be difficult and time consuming so, under the Premiam programme, a database of key suppliers and recognised experts has been compiled as a resource for those coordinating monitoring. This also identified gaps in national and regional expertise and skills. However, such an inventory is vulnerable to quickly going out of date unless maintained effectively and means of doing so has not been resolved at the time of writing.

3.3. Equipment

As with skills and expertise the identification and availability of key equipment is essential. This relates to basic consumables such as bottles, bags and buckets and more specialised sampling equipment such as sediment grabs and fishing trawls. The availability of sampling vessels, a resource with clear regional importance, is also key to a prompt response. Under the UK Premiam programme key equipment and availability were also included in the database mentioned above. However, as with a skills inventory, any database is unlikely to remain current for long unless routinely updated. An alternative to a 'dispersed equipment' inventory, the maintenance of emergency monitoring equipment stockpiles, is also under consideration.

3.4. Funding

No effective monitoring programme can be launched without the necessary funding, and the UK has no clearly identified national marine monitoring fund for use following incidents. Therefore, it will inevitably fall to government to fund any initial monitoring activity and this is further complicated by the fact that certain responsibilities in this area have been devolved to separate authorities in England, Scotland, Wales and Northern Ireland. As a result negotiations have been initiated among the necessary authorities to understand the requirements and establish such a fund as necessary. At the time of writing a small government fund, enough to start immediate baseline monitoring has been agreed by authorities with responsibility for English waters.

3.5. Responsibility and management

Within the UK, a process for identifying and forming an expert group to manage monitoring activities has been developed. This group has been named the Premiam Monitoring Coordination Cell (PMCC) and the PMCC chair is selected on the basis of being a recognised expert in the field of post-spill monitoring. Due to different regional governmental organisation separate guidance is being put in place for each of the nations of the UK, but based on consistent core principles. The embedding of these arrangements is being driven by their inclusion in the UK National Contingency Plan (currently under review).

The PMCC has a number of key responsibilities when an incident requires its formation:

- The initiation and development of a coordinated monitoring programme in line with the Premiam post-spill monitoring guidelines (Law et al., 2011).
- The formation and management of a 'monitoring team' to undertake the monitoring activities.
- The maintenance of strong communication links to any other response and advisory groups, for instance, under Civil Contingency arrangements.
- The management and maintenance of financial and expenditure records pertaining to all monitoring activities.
- Overseeing the generation and publication of reports as necessary.

3.6. Integration and coordination

In the UK it is anticipated that the PMCC will take an overview of all potentially relevant monitoring and data gathering activities including those from governmental, academic, industry and local interest group sources and help to coordinate these. It is the responsibility of the PMCC chair to integrate all relevant monitoring activities into any update reports and the final incident impact assessment.

3.7. Support and buy-in

The development and maintenance of broad support and buy-in for the guidance and processes developed within Premiam has been the responsibility of a steering group of UK government department and agency representatives. This group meets at least on an annual basis and includes all the organisations responsible for the environmental status of UK marine and coastal waters, conservation, response and regulation of the shipping and offshore oil & gas industries. A website is maintained (www.cefas.defra.gov.uk/premiam) and a bi-annual conference is arranged (first held in 2012 with a 2nd conference due in 2014).

3.8. Practice

In the UK, national and regional exercises are held regularly, organised by a number of government agencies, response organisations and ports. Historically these have focussed on the core activities of search and rescue, counter pollution/response mobilisation, command and control and the provision of scientific advice. The mobilisation of monitoring activity has not formed part of previous exercises and, to date, this has still not been effectively incorporated into exercise operations and remains to be done.

4. The preparedness assessment for post-spill monitoring

In the following section an approach is described, based on the principles for post-spill monitoring described in this paper, that enables a preparedness assessment for a given scenario to be made. In considering preparedness in this context, stakeholders might ask a number of questions including:

- Do we know what to do?
- Can we respond quickly enough?
- Do we know what are our responsibilities and those of other stakeholders?
- Do we have or have access to the right expertise and knowledge?
- Is the necessary sampling and monitoring equipment available and ready for use?
- Can we manage the necessary logistics and communications involved?
- Do we have the necessary support and funding to do this properly?
- Is our pre-planned response to environmental monitoring proven to work?

4.1. The monitoring preparedness assessment matrix (MPAM)

The monitoring preparedness assessment matrix (MPAM) (Table 1) is a tool that puts the types of preparedness questions mentioned above into an organised framework for assessment purposes. Each of the eight principles of effective monitoring programmes are considered in the matrix as indicators of preparedness level which the user can judge their own situation/scenario. The preparedness levels are rated on a 1–5 scale, representing a range of situations from underprepared to fully prepared, respectively. The preparedness level assignments for each of the principles can then be summed to provide an overall monitoring preparedness assessment score (MPAS) ranging between 8 and 40. The MPAS value can be considered as an overall indication of the preparedness level for the situation/scenario under consideration but, more importantly, the process can highlight specific areas in which improvement is needed.

4.2. Assessing preparedness for post-spill monitoring

Examples of how a monitoring preparedness assessment score (MPAS) is derived are shown in Table 2 by referring to a number of scenarios for illustrative purposes. Using a red-amber-green (RAG) approach in the assessment also allows a more visual representation to be generated which is useful for comparing several scenarios on a qualitative basis.

For illustrative purposes the two last major incidents in UK waters that required a substantial monitoring programme to be implemented have been selected. The *Sea Empress* incident took place in 1996 at the entrance to Milford Haven in Wales. Approximately 72,000 tonnes of Forties crude oil were spilled, seriously affecting local coastlines and fisheries, although effects were limited by extensive use of dispersants (Law and Kelly, 2004). The *MSC Napoli* incident involved a container ship that was grounded in Lyme Bay on the South coast of England in 2007. A small amount of fuel oil was spilled but there were also a wide range of hazardous and noxious substances (HNS) identified in the cargo manifest and a monitoring programme was established, coordinated by Cefas (Kelly et al., 2008; Law, 2008; Law and Kelly, 2008). The assessment for these two events (scenarios 1 and 2 in Table 2) reflects the situation at the time the incidents occurred. At the time of the *Sea Empress* spill, little pre-consideration had been given to the necessary guidance, funding and coordination issues from an environmental monitoring perspective and, while it is recognised that there was generally good national availability of skills and equipment, (Sea Empress Environmental Evaluation Committee final report, 1998; Edwards and White, 1999), this was not well coordinated. By 2007, at the time of the *MSC Napoli* incident, some issues around responsibility and management had been improved as a result of the Donaldson report (Department of Transport, 1994) including the implementation of the Secretary of State's representative (SOSREP) role and the formation of a number of regional standing environment groups (SEGs) to provide environmental advice to the response cells. Nevertheless, there were neither specific monitoring guidance in place nor a coordinated procedure for initiating it. Using the MPAM an MPAS of 18 is generated for the *Sea Empress* scenario and 21 for the *MSC Napoli* which is indicative of the relatively low level of preparedness at that time for initiating post incident monitoring. This is borne out by the fact that the, eventually very effective, Sea Empress Environmental Evaluation Committee (SEEEC) was not formed until several weeks after the incident occurred.

Assessments for scenarios 3 and 4 (Table 2) represent the potential monitoring preparedness levels for equivalents of the *Sea Empress* and *MSC Napoli* incidents were they to happen today. The MPAS values of 25 and 28 for the *Sea Empress* and *MSC Napoli*, respectively, indicate an improved preparedness situation and an overall assessment for both of 'Prepared (but with weaknesses)'. The assessments still highlight significant room for improvement and the comparison of scenarios 1 and 2 to 3 and 4 illustrate a key use of the assessment process as a means through which progress and improvement can be assessed and recorded. When dealing with incidents actual past experience of managing such complex situations is invaluable. In general, experience is positively correlated with preparedness and thus increases the likelihood of responsiveness. Nations that have experienced several incidents are more likely to improve the process than nations or regions that have never experienced a spill incidents and therefore to respond more effectively.

Finally, Table 2 includes an assessment of two hypothetical scenarios (Nos. 5 and 6) at opposite ends of the perceived complexity scale. Scenario 5 represents a subsea oil blow out potentially requiring dispersant injection in the deep and challenging environment west of the Shetland Isles, whereas scenario 6 represents a relatively small oil spill close to an easily accessible coastline in England, which might be considered as relatively 'routine'. For the subsea incident west of Shetland, the challenging nature and remoteness of the environment would mean that the necessary skills, experience and specialised equipment would be more difficult to source. Furthermore, there may be uncertainty from where

Table 1
The monitoring preparedness assessment matrix.

No	Principle	Preparedness level				
		1	2	3	4	5
1	Scientific Guidance	No guidance identified/available.	No specific guidelines, with access to relevant guidance available but not necessarily agreed by all stakeholders.	No specific guidance in place but identified source(s) disseminated and agreed by stakeholders.	Fully comprehensive general principles and guidance available. Agreed by stakeholders as the 'standard' to be used.	Fully comprehensive guide(s) relevant to specific scenario(s). Agreed by stakeholders as the 'standard' to be used.
2	Skills & Knowledge	Major gaps in availability in several key skills and knowledge areas.	Substantial gaps in availability in several key skills and knowledge areas.	Some uncertainty regarding skills availability but expected to be sufficient.	Providers of all necessary skills identified, but not necessarily fully engaged.	Providers of all necessary skills identified and fully engaged.
3	Equipment	Major gaps in sources and availability of key monitoring equipment.	Substantial gaps in source and availability of key monitoring equipment identified. Basic sampling equipment sources available.	Sources of key monitoring equipment identified. Uncertainty around equipment for specialised functions or extended programmes.	Sources of all monitoring equipment identified but uncertainties about availability.	Sources of all monitoring equipment identified with guarantees of short-notice availability.
4	Funding	No promptly accessible funding source identified. Key potential funders do not accept responsibility to fund.	No agreed up-front funding identified. Likely sources known but some uncertainty around access and responsibility to fund.	No up-front funding identified, but parties responsible for funding agreed. Possible uncertainty around prompt access to funding and the size of funding available.	Up-front funding identified and promptly accessible. Potential uncertainty for funding of monitoring on a very large scale or over the long-term.	Promptly accessible and fully sufficient funding set aside with clear responsibility.
5	Responsibility and Management	No clarity on which body has responsibility for making decisions regarding monitoring.	Generally understood which organisations would manage the monitoring programme, but some uncertainty over roles and responsibilities	Generally understood which organisation would manage the monitoring programme, with an expectation that a clear process would be put in place promptly.	Clear process for decision making and management of monitoring programme, but no named individuals or coordinating group identified.	Clear process for decision making and management of monitoring activity, with named individuals identified for important roles.
6	Integration & Coordination	Little integration. Different stakeholders likely to act in isolation.	Substantial gaps in communication between key bodies. Some uncertainty on how monitoring would be coordinated effectively.	Good general links between key bodies. Expected to 'pull together' during an incident.	Full integration between key government authorities. All other sources of monitoring activity identified but not necessarily engaged.	Fully integrated programme with good links between government, industry and academia.
7	Support & Buy-in	Relevant systems and processes conflict with no agreement between key parties.	No declared support from across all stakeholder groups. Some disagreement/ uncertainty but no obvious conflict.	Substantial agreement and support amongst key bodies (i.e. government authorities). No major support sought across all stakeholders groups.	General support and buy-in across stakeholders with strong support from key bodies (i.e. government authorities). Some activity on wider stakeholder engagement	Full support and buy-in across all stakeholders for the process, including declarations of support. Regular activity promoting broad stakeholder engagement.
8	Practice	Monitoring activity not included in emergency response exercises. Little or no links between the responsible bodies.	Inclusion of monitoring in exercises 'in principle' but no specific activity to date.	Included as part of scheduled emergency response exercises. But not recently (> 1 year ago).	Integration into regular emergency response exercises (but not necessarily including physical deployment of assets)	Full integration of monitoring and communications into regular emergency response exercises (including physical deployment of assets)

Overall Monitoring Preparedness Assessment Score (MPAS)	8 - 12	13-20	21-28	29-35	36-40
Level	**Underprepared**	**Low preparedness**	**Prepared (but with weaknesses)**	**Generally Prepared**	**Fully Prepared**

Table 2
Illustrative examples of monitoring preparedness assessments for a range of scenarios demonstrating how the monitoring preparedness assessment score (MPAS) is derived.

No.	Scenario	Scientific Guidance	Skills & Knowledge	Equipment	Funding	Responsibility & Management	Integration & Coordination	Support & Buy-in	Practice		MPAS
1	Sea Empress 1996	2	3	3	2	2	3	2	1		**18**
2	MSC Napoli 2007	2	3	3	3	3	3	3	1		**21**
3	Sea Empress equivalent 2014	4	4	3	3	3	3	3	2		**25**
4	MSC Napoli equivalent 2014	4	3	3	4	4	4	4	2		**28**
5	Subsea release - West of Shetland 2014	3	2	2	2	4	4	2	2		**21**
6	Small localised oil spill near English coast 2014	4	5	4	5	5	4	5	2		**34**

NB: The preparedness levels allocated to each scenario in Table 2 are indicative only for the purposes of this paper and have not been derived through expert consultation.

the necessary funding would be provided, so there are a range of level 2 scores, indicating relatively low preparedness, across a number of the principles. Conversely, for a relatively small oil spill on an easily accessible coastline, there are well established skills and understanding and (for England) there are clear lines of funding and responsibility in place for such incidents. The overall MPAS scores for these hypothetical scenarios are 21 and 34 for the west of Shetland and small coastal oil spill, respectively, indicating that, for the latter, a general level of preparedness can be concluded but there are some weaknesses in the preparedness level for the more challenging scenario.

4.3. Applications of the process

The assessment process described above, using the MPAM to generate MPAS values, can be used for a number of purposes that can help in emergency response preparedness assessment, planning and monitoring.

4.3.1. National/regional/local assessment

Using a generic scenario, or one that is recognised as of highest risk/likelihood of occurring, the MPAM can be used to understand the general post spill monitoring preparedness level in a country, region or local area. Generating the MPAS should be done in consultation with all the main relevant stakeholders for the nation, region or local area in question.

4.3.2. Organisation/team assessment

Similarly to the use outlined above, using an appropriately selected relevant scenario, the MPAM can be applied to a single organisation or discrete team that has a responsibility pertaining to the management and/or conduct of post-spill environmental monitoring. This can be useful for understanding where investment and/or training is required and for identifying issues on which the organisation need to engage more actively with other stakeholders.

4.3.3. Specific scenario assessment

Every marine spill scenario is different and the nature of the required monitoring programme will depend on many factors including; what has been spilled (oil, HNS etc.), the size of the spill, the location of the incident and the nature/sensitivity of the receiving environment. The MPAM can be used, therefore, to investigate preparedness levels for a range of spill scenarios and, in conjunction with risk assessment and probability analysis, provide a strong tool to focus training and investment.

4.3.4. Preparedness auditing and improvement monitoring

The MPAM and the generated MPAS values can be used as part of a preparedness auditing process. Furthermore, if conducted periodically and compared the MPAS values and profiles can be used to monitor improvements in preparedness or to highlight where a degradation of preparedness level is evident.

4.3.5. Preparedness perception and reassurance

The MPAM can also be used to measure the level of preparedness that is perceived by different individuals or groups. Most monitoring programmes will require the coordinated efforts of several organisations and their effectiveness as a team will be affected by their collective understanding of roles, responsibilities and resource availability. If the MPAS is generated by all relevant stakeholders for a common scenario the differences between their assessments can highlight areas where there are gaps in the collective understanding that could lead to misunderstandings or uncertainty in the event of a real incident. This process would be useful as part of response exercises. The MPAM and the eight principles can also be used as the basis on which to explain to key stakeholders (e.g. the public) the level of preparedness and thus can be used as part of a communications and reassurance strategy.

5. Conclusions and recommendations

A fully effective post spill environmental monitoring programme relies on preparedness. Appropriate scientific guidance and access to the necessary skills and equipment are, of course, essential, but just as important is the coordination and management framework in which the monitoring takes place. Therefore, clear lines of responsibility and decision making are important as well as identified funding sources and the integration of all stakeholders' activities. In this paper eight principles of effective monitoring have been defined as the basis on which a fully effective programme can be planned and conducted.

Using these eight key principles a tool for the assessment of monitoring preparedness has been described and its use demonstrated. The monitoring preparedness assessment matrix (MPAM) has been introduced as the tool through which a monitoring preparedness assessment score (MPAS) can be generated as an indication of the level of preparedness. The use of the process has been illustrated through a number of examples and the primary applications of the approach have been described. The MPAM tool can be applied to national, regional or local areas or discrete organisations/teams as a means of assessing current status and can also be used to consider preparedness levels for a range of different scenarios.

It is recommended that national, regional and local authorities consider using the type of approach described here to identify the current status of monitoring preparedness and to prioritise areas for investment and improvement. Key stakeholder organisations that have a role in the management or conduct of post spill monitoring would also benefit by using the MPAM as part of assessing their own preparedness status and could help to inform areas for training and improved engagement with other stakeholders.

Finally, it is recommended that the process is used as a means of improving team working and collective understanding across organisations that need to work together during emergency response and environmental monitoring activities. An analysis of preparedness perceptions using the MPAM tool can help identify gaps in collective responsibility and areas of potential misunderstanding which can be addressed in advance of the need to work together in a real incident.

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