

OSPAR Guidelines for Monitoring the Environmental Impact of Offshore Oil and Gas Activities
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1 INTRODUCTION

1. At its meeting in 1999, OSPAR adopted a “Strategy on Environmental Goals and Management Mechanisms for Offshore Activities”. A key element of the strategy is the assessment of the effectiveness of measures adopted for the prevention and elimination of pollution of the maritime area. Monitoring is an important aspect of such assessments. In June 1988 the Paris Commission adopted the Guidelines for Monitoring methods to be used in the vicinity of platforms in the North Sea. These guidelines were based on the overall objective of environmental monitoring, namely to assess the effects and extents of discharges being made at that time. Since then, the scale of activity in the maritime area has increased. New field developments have occurred and new production technologies have been introduced (e.g. sub-sea structures, changeover from oil-based to alternative drilling mud) and the quantities of produced water being discharged have increased. Moreover, a broader range of concerns about potential impacts of the offshore industry has been expressed. OSPAR has therefore recognised that a coordinated chemical and biological effects monitoring programme is essential for identifying the nature and extent of environmental impacts. However, not all the tools and methods needed for the undertaking of such monitoring (in particular water column impacts) have yet been fully developed or validated. This document is designed to provide guidance on the design and conduct of monitoring programmes under the range of differences that exist between different production areas. Consistency in monitoring guidelines is emphasised, both with respect to the selection of parameters and the approach to sampling and analysis. The application of quality assurance protocols (where they exist) will enable the results of the investigations to be compared from year to year and evaluated holistically across the entire area.

2 PURPOSES

2. The aim of these OSPAR guidelines is to harmonize monitoring of environmental impacts of discharges from offshore installations, and to harmonise reporting and assessment of the data. The monitoring has the following main purposes:

- to provide the necessary information for assessing the effectiveness of reduction measures;
- to establish the spatial distribution and extent (with respect to a reference) of substances released from installations;
- to establish the spatial distribution and extent of biological effects;
- to establish temporal trends in order to estimate the magnitude of changes over time;
- to identify unforeseen impacts and new areas of concern;
- to create the background to develop prediction of expected effects and the verification thereof (hindcasting).

3. In general, impact concerns should be addressed during all phases of petroleum activities and might cover aspects such as:

- spatial and temporal changes in sea-bed contamination and biological community structure;
- impact on pelagic organisms and water column systems;
- contamination mediated through the food chain;
- impact on specific natural resources.

4. The focus of these guidelines lies presently on the monitoring of spatial and temporal changes in sea-bed contamination and benthic animal community structure and on impacts on pelagic organisms and water column systems.

3 SAMPLING STRATEGY

5. In the OSPAR region the offshore industry operates within a range of different environments from shallow seas with very mobile sediments to deep, more stable waters with fine sediments. Monitoring needs to be fit for purpose and to take account of local and regional differences, operational practices, past and current field activities and discharges, and what is known about impacts from previous work. Contracting

Parties (CPs) designing monitoring programmes should refer to the work of relevant ICES and OSPAR working groups and should take account of relevant OSPAR guidelines and international standards for technical aspects, and should pay particular attention to statistical requirements when designing their programmes. A list of the most relevant OSPAR guidelines and international standards is given in Technical Annex 1.

6. Monitoring programmes will need to maintain a flexibility of approach in particular with regard to the development of improved methodologies. The types of survey to be conducted, their coverage, their repeat frequencies and timing should be dependent primarily on the natural local conditions in the area and the activities that are subject to monitoring. These points are expanded further in the Technical Annexes 2 and 3.

4 QUALITY ASSURANCE

7. Quality assurance is an essential part of environmental monitoring programmes. The contractor company used for environmental monitoring studies must be able to document that it, or its subcontractors, is accredited, or is in the process of seeking accreditation, according to the relevant ISO standards. Accreditation shall include all aspects of the work, from sample collection and analysis to presentation of the results. Exceptions can be made for activities for which no official approvals exist. For these types of analyses the contractor must be able to document that it has established quality control to at least ISO-9001/9002 and follows the relevant guidelines for the relevant type of sampling, sample analysis and reporting.

5 REPORTING

8. It is important that monitoring data and results are reported to the CPs in a uniform way and are interpreted in a consistent manner. Data reporting should be in accordance with any OSPAR requirements and with the latest ICES reporting formats, and should be accompanied by information on methods used, detection limits, results of analysis of certified reference material and any other comments or information relevant to an ultimate assessment of the data. In order to establish acceptability of the data, they should be reported, where appropriate, together with the dates and results of participation in intercalibration exercises and summary information from recent control charts, including dates, sample sizes, means and standard deviations. In reporting the results of replicate samples it is important to describe the replication procedure fully. As part of the reporting CPs will assess the results of their programmes in order to judge the effectiveness of the measures used to control the environmental impact of their offshore industries. They should also submit their results and/or assessments to the relevant OSPAR/ICES working groups. This will enable the wider appraisal of their findings and allow continuing improvements in monitoring approaches to be introduced.

TECHNICAL ANNEX 1: OSPAR GUIDELINES AND INTERNATIONAL STANDARDS OF RELEVANCE TO SEDIMENT AND WATER COLUMN MONITORING RELATED TO OFFSHORE ACTIVITIES

JAMP Eutrophication Monitoring Guidelines: Benthos (Ref no 1997 - 06)

JAMP Guidelines for Monitoring Contaminants in Sediments (Ref no 2002-16)

JAMP Guidelines for General Biological Effects Monitoring. OSPAR Commission, (Ref no 1997-07)

JAMP Guidelines for Contaminant-Specific Biological Effects Monitoring. OSPAR Commission. (Ref no 2003-10)

EN-ISO 5667-19: 2004: Water Quality – Sampling – Part 19: Guidance on sampling in marine sediments..

ISO/TC/147/SC5/WG11: Water Quality: Guidelines for quantitative investigations of soft bottom benthos in the marine environment (in prep.)

ISO 11277:1998: Soil quality - Determination of particle size distribution in mineral soil material -- Method by sieving and sedimentation.

TECHNICAL ANNEX 2: RECOMMENDED PROCEDURES FOR SEDIMENT MONITORING RELATED TO OFFSHORE ACTIVITIES

1 INTRODUCTION

9. This Annex describes the recommended procedures that should be used when assessing the nature and area extent of impact from contaminants discharged during the various phases of development of offshore oil and gas activities. These will include assessment of patterns of contamination, the rate and direction of any changes in those patterns, and of any effects on macro-benthic community structure.

2 MONITORING STRATEGY

10. Monitoring programmes should comprise both baseline surveys prior to any petroleum development and follow-up surveys during exploration, production and decommissioning. Baseline or initial surveys will provide data on the existing environment and will assist with the design of future monitoring programmes. Follow up surveys will provide information about the nature and direction of any changes. Different offshore development phases and activities, and local environmental conditions will demand different monitoring frequencies and survey strategies to be established. In general, two different approaches may be applied: field specific monitoring and wider area (regional) monitoring. Particular attention should be paid to the OSPAR lists of relevant chemicals (OSPAR Convention, Annex 2, OSPAR Strategy with regard to Hazardous Substances, OSPAR List of Chemicals for Priority Action, OSPAR List of Substances/Compounds Liable to Cause Taint).

2.1 Field specific monitoring

11. Field specific monitoring should be based on a baseline survey and should address spatial and temporal trends in contamination and effects within the impact zone of an offshore petroleum field or installation. The focus should be on the verification of predicted impacts at individual fields. These monitoring programmes should start shortly after drilling activities have started. Consecutive field specific monitoring should be integrated into wider area (regional) monitoring programmes where these are in place.

2.2 Wider area (regional) monitoring

12. In order to put offshore industry installation impacts into a more holistic context, co-ordinated wider area (regional) surveys should be conducted. Such monitoring should describe general environmental background levels in addition to data from the field specific monitoring in the region and will provide information on large-scale environmental patterns and enable the added effects of adjacent installations in areas of intense offshore activity to be assessed.

13. The regional monitoring should describe general environmental levels distant from the installations and the integrated impact of offshore activities in a wider area.

3 TIMING

14. To facilitate inter-annual comparison, fieldwork for baseline and monitoring surveys should be carried out in the same season each year. Sediment surveys should preferably be carried out in spring in order to avoid problems related to newly settled juveniles of benthic fauna. These recruits may at times dominate the fauna numerically, but must be regarded as transitory members of the fauna since natural mortality after settling may be very high.

4 STATION POSITION PATTERN

15. Station positions should be chosen in a way that will allow the spatial impact of offshore developments to be detected. Ideally, the station pattern for baseline and monitoring surveys should be identical. In practice, a baseline survey will comprise a more elaborate station pattern (and possible also measure more parameters) because the *a-priori* knowledge, necessary for the design of effective monitoring is insufficient or lacking. Station locations both for field specific and wider area surveys should be defined on the basis of bottom topography, sediment characteristics, current conditions and other relevant parameters. Areas with high fractions of silt /clay sediments, where contaminants are likely to accumulate, deserve particular attention.

4.1 Stations for field-specific monitoring

16. The orientation and extent of the station pattern should be based on the predicted area of influence as determined by dispersion modelling, discharge scenarios and local environmental conditions. In cases where the exact locations of the planned installations are known and the environment is homogeneous with respect to sediment types, depths, and currents, and where the aim is to assess possible gradients in impact radiating from a point source, a radial transect station design may be most suitable. If a prevailing current direction exists, there should be a preponderance of stations in that direction. The station network should also include at least one unaffected station in all four main directions away from the point source. For field specific monitoring, a minimum of three reference stations should be selected in geographic proximity to the field so as to reflect the local, natural physical, chemical and biological conditions at the monitoring site. As an example these reference stations may be placed at minimum 10 000 m distance from the point source(s) in a direction perpendicular to the main current, but care must be taken to ensure that all stations in a field or wide area are comparable with respect to physical and chemical properties. If field specific monitoring is coordinated with wide area monitoring, stations in the latter may serve as reference stations.

17. An example of a commonly used field specific design is given in Table 1. Other options for station position designs are e.g.: grids covering the survey area, set number of stations within predefined impact and control areas respectively as basis for a BACI (Before-After-Control-Impact) assessment (Petersen, 2000).

18. There are statistical tools available (power analyses) that allow the estimation of the number of stations required to detect a predefined change in a measured parameter with a certain confidence over a certain number of consecutive surveys. It is highly recommended that such analyses be considered in the planning of the surveys. In order to be able to select representative monitoring and reference stations, the number of stations sampled during a baseline survey should be larger than that expected necessary in subsequent monitoring programmes.

19. The station network for field-specific monitoring should be finalised once the installation(s) and final discharge point(s) have been established. It should include as many as possible of the stations established for the baseline survey. It is desired that consistency in the distribution of sampling stations be maintained throughout the monitoring period to facilitate interpretation of spatial and temporal trends. If initial results show that the impact associated with a field extends beyond the outermost stations, the station network should be extended accordingly. New industrial activities and results from monitoring may also call for the establishment of new stations.

Table 1: Example of transect based station network for monitoring of sediments at an individual installation, where the residual current direction is along the 0° axis. Reference stations are shown in brackets.

Direction relative to residual current	Station Numbering	Distance from origin (m)
0°	1	250
	2	500
	3	1000
	4	2000
	5	4000
		(min. 10 000 (ref. st.))
90°	6	250
	7	500
	8	1000
	9	2000
		(min. 10 000 (ref. st.))
180°	10	250
	11	500
	12	1000
	13	2000
	14	min. 10 000 (ref. st.)
270°	15	250
	16	500
	17	1000
	18	2000

4.2 Stations for wide area monitoring

20. The number and positioning of sampling stations necessary to describe the environmental conditions in a wider region covering several offshore fields cannot yet be advised with any certainty. It will depend on how the region is delimited, and on the range in depths, sediment types and currents present. It is likely that many more samples at many more stations will need to be taken for a satisfactory description of the sea floor in a region than to describe a single field. The use of power analysis to support survey design will be critical. Stations should be positioned at a variety of distances from known or planned discharge points. It will be essential that trials are undertaken and the experience gained from those trials is used to improve subsequent survey practice. For regional monitoring on the Norwegian shelf, where the regions are defined by whole degrees latitude, a minimum of 10 such stations are established in each region on basis of a regional baseline survey. If a new field is developed in the region, the need for additional reference stations should be considered.

5 ANALYTICAL PROGRAMME

21. This chapter outlines recommended parameters, sampling procedures and analytical methods that should be implemented in point sampling monitoring of offshore discharges and impacts. Sampling equipment, sample collection, and treatment and storage of samples should be in accordance with the JAMP Guidelines for monitoring contaminants in sediments (Agreement 2002-16) and the JAMP Eutrophication Monitoring Guidelines: Benthos (Agreement 1997-06). The following conditions of the sediment should be monitored:

5.1 Sediment appearance at sampling

22. The following should be described for all types of survey as soon as a sample is secured on deck of the sampling vessel:

- visual description of the sediment surface (e.g. presence of drill cuttings, debris, empty shells),
- presence of large and/or conspicuous fauna,
- sediment colour (e.g. by referenced to the "Munsell Soil Colour Chart System", Munsell Colour, Maryland, U.S.A.),
- smell (e.g. H₂S or oil).

5.2 Sediment Analysis

5.2.1 Grain Size Distribution

23. Homogenised samples may be made from the replicate samples collected at each station. For grain size distribution analysis the procedure given by Buchanan (1984) or ISO standard 11277:1998: Soil quality - Determination of particle size distribution in mineral soil material - Method by sieving and sedimentation is recommended, characterising the size distribution in 0.5 or 1 phi intervals from 2000µm – 63 µm. The silt/clay fraction (< 63 µm) may be further analyzed by e.g. sedimentation (pipette or sedigraph) or laser granulometry. The weight of each sediment fraction should be determined (to the nearest 0.01 g) as basis for calculating the cumulative weight percent distribution for each station. Median particle diameter, standard deviation, as well as skewness and kurtosis of the grain size distribution may be calculated from the same analyses.

5.2.2 Total Organic Carbon (TOC)

24. Although a recommended procedure has not yet been agreed upon, total organic carbon is a useful parameter *for* normalisation of other determinants. The size fraction analysed should be consistent with other analytical techniques (see JAMP Guidelines for Monitoring Contaminants in Sediments, Technical Annex 5).

5.2.3 Hydrocarbons and Synthetic Drilling Fluids

25. Sampling and analysis for these organic contaminants should in general follow the JAMP Guideline Agreement 2002-16 (covers only PAHs). Analysis of sediment hydrocarbon content may comprise a range of parameters depending on the purpose of the monitoring and the discharge history of the field/area in question. The sediment extraction may be performed by either saponification (IOC/UNESCO, 1982) or by Soxhlet or cold solvent extraction procedures. If a different extraction procedure is used, the results obtained must be comparable to those outlined above. Removal of the polar fraction from the extract may be done by adsorption chromatography (florisil or silica). Appropriate certified reference material should be used (e.g.

PAH contaminated soil (CRM 103-100) and Petroleum crude oil (Standard Reference Material 1582)). Detection and quantification limits should to be calculated according to the guidelines issued by the ACS Committee on Environmental Improvement (1980).

26. The most commonly requested hydrocarbon parameters in offshore monitoring are:

Total hydrocarbon content (THC)

27. THC analyses should be performed with GC/FID in an appropriate retention window (e.g. C₁₂ to C₃₅) using an appropriate internal reference standard.

PAHs

28. The PAH-compounds to be analysed should be those on EPA's "list of 16 compounds". PAHs should be quantified by GC/MS according to JAMP Guideline Agreement 2002-16, Technical Annex 3. In some instances, total 2-6 ring parent and branched PAH analysis might be desirable.

The oil specific group of aromatic hydrocarbons called NPD

29. NPDs are the sum of naphthalene, phenanthrene/anthracene, dibenzothiophene and their C₁-C₃ alkyl-homologues.

Decalines (C₅-C₈ alkyl-decalines)

30. These should be analysed if low-aromatic drilling fluids have been used at a field.

Selected component(s) of synthetic drilling fluid(s)

31. These should be analysed if synthetic drilling fluids have been used on a field. The analytical methods must be adapted as appropriate to the specific compounds being analysed. A relevant internal standard should be used for quantitative determination. A sample of the drilling fluid(s) in question should be used as reference material.

32. In general analysis of NPDs, PAHs, and decalins should be performed only at stations where THC levels are significantly higher than background.

5.2.4 Metals

33. Apart from barium being an indicator of discharges of drilling fluids, most metals from the offshore industry are introduced to the sediment environment as impurities in the barite used in the drilling fluids, and therefore occur at relatively low concentrations. Higher concentrations may, however, occur in drill cuttings due to the mineral composition of the formation drilled. The most relevant elements are Cd, Cr, Pb, Cu, Hg, and Zn.

34. Sampling of sediments for metal analysis should follow the JAMP Guideline Agreement 2002-16. The procedures for metal analyses are partially based on recommendations from OSPAR/ICES (1990 and later revisions). Generally the < 2mm fraction of dried sediments should be ground, leached using an appropriate method e.g. HF/Aqua Regia (Loring and Rantala, 1992), and analysed using an appropriate technique. High levels of Ba may need to be analyzed by a fusion method (e.g. Hartley, 1996). Quality control should be established and comparability between different analytical procedures ensured through analysis of suitable and certified reference materials. The selected reference materials should be marine sediments with both high and low contaminant concentrations and certified for the correct leaching method.

5.2.5 Benthic macrofauna

35. Sampling, sample handling and analysis of macro-benthic fauna should be done according to JAMP Agreement 1997-06, Technical Annex 2 (Soft bottom macrozoobenthos). Taxonomic name as well as number of individuals should be determined for all species. As a rule taxonomic resolution should be at the species level, but for some taxonomic groups (for example Oligochaeta, Cnidaria, Solenogastres and Phoronida) this will demand techniques and expertise which is not readily available. For such groups it may be necessary to determine morphological forms only, but this strategy will in general adequately fulfil the requirements for the subsequent numerical analyses. The nomenclature should be in accordance with the latest international revisions, e.g. the European Register of Marine Species (the results of a recent EU project covering almost 30.000 species). Information on the Register can be sought at: <http://www.erms.biol.soton.ac.uk>.

36. Organisms belonging to Porifera, meiofaunal groups such as Harpacticida and planktonic organisms such as copepods and mysids, together with fish, may be identified and recorded when appropriate, but they should be excluded from the calculation of the community indices as well as from multivariate analyses of community structure. Species determinations should be carried out for solitary, but not colonial Hydrozoans.

A full species list (species names and number of individuals per species) should be made for each replicate sample obtained.

37. The taxonomic resolution should be consistent throughout the monitoring programme of a field/region.

38. For certain purposes biomass of each species may also have to be determined (cf procedure referred to in JAMP Agreement 1997-06, or Ruhmor (1999)).

39. There is a certain inconsistency in defining the term macro-fauna among different countries. Some use fauna above 0.5 mm and others use fauna above 1 mm. To ensure comparability it is recommended that, when using 0.5 mm sieving, the sample should be split into two fractions prior to fauna analysis: one fraction containing the animals > 1 mm, and one with those between 0.5 and 1 mm. The two fractions should be analysed separately. The added effort in doing this is considered to be minimal, and the procedure will result in one station-by-taxon matrix for the > 0.5 mm fraction and one for the > 1 mm fraction.

Table 2: Overview of the recommended number of sediment samples and sub-samples to be taken at different types of stations and for different types of surveys.

Analysis parameter	Baseline survey		Monitoring survey			Conservation / sample quantity
	Field Station	Reference Station	Field Station	Reference Station		
TOC ^{a)}	3 samples 0-1 cm	3 samples 0-1 cm	3 samples 0-1 cm	3 samples 0-1 cm		-20°C
Grain Size Analysis ^{c)}	1 sample 0-5 cm	1 sample 0-5 cm	1 sample 0-5 cm	1 sample 0-5 cm		-20°C 100 g
Total Hydrocarbons THC	3 samples 0-1 cm	5 samples 0-1 cm	3 samples 0-1 cm	5 samples 0-1 cm		-20°C 300 g
PAH, NPD, decalines ^{e)}	1 sample ^{b)} 1-3 cm	1 sample 1-3 cm	1 sample ^{b)} 1-3 cm	1 sample 1-3 cm		
	1 sample ^{b)} 3-6 cm	1 sample 3-6 cm	1 sample ^{b)} 3-6 cm	1 sample 3-6 cm		
Synthetic Drilling Fluids	As for THC	As for THC	As for THC	As for THC		-20°C 300 g
Metals - Ba, Cd, Cr, Cu, Pb, Zn, Al, Li ^{d)} - Hg ^{e)}	As for THC	As for THC	As for THC	As for THC		-20°C 50 g
Benthic fauna	5 samples	10 samples	5 samples	10 samples		10 % formaline Rose Bengal / Eosin

a) Separate samples not taken. Material is to be obtained from samples collected for collected for hydrocarbon or metal analysis

b) Conducted at 2 stations, 250 m and 2000 m downstream of the installation.

c) Mixed sample from three grab samples collected at each station

d) Al or Li for normalisation purposes (selection depending mineral composition of the sediments monitored)

e) Conducted at reference stations and 2 other stations, 250 m and 2000 m downstream of the installation.

5.3 Statistical analyses

40. The statistical analyses of the monitoring data will depend on the type and purpose of investigation. A minimum requirement for general description of individual parameters and stations should be that average values are adjoined by summary statistics, such as min., max. and SD or SE.

41. Where the purpose of the chemical analyses is to identify stations that are contaminated, means to calculate the limit of significant contamination above background should be agreed upon a priori. One recommended procedure is to calculate this limit by use of a one-tailed Students t-test on the average parameter value of a set of background stations and with a confidence limit of e.g. 95 %.

42. Numerical analysis of bottom fauna data should comprise both univariate and multivariate methods. Statistical analyses should be performed on the entire set of benthos data. Newly settled juveniles of benthic species may at times dominate the macro-fauna numerically, but due to heavy natural post-settlement mortality, such dominance must in many cases be regarded as transitory and not as an indicator of the prevailing bottom conditions. Should juveniles appear among the ten most dominant organisms in the data set, the statistical analysis should be conducted both with and without these in order to evaluate their importance. Differences in fauna structure between reference stations and field specific stations should be assessed by researchers skilled in statistical interpretation of benthic community data, and with emphasis on the multivariate analyses. All results should be standardised to a sediment surface area of 0,5 m². A general overview of suitable statistical methods is given by e.g. Gray *et al.* (1988).

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TECHNICAL ANNEX 3: RECOMMENDED PROCEDURES FOR WATER COLUMN MONITORING RELATED TO OFFSHORE ACTIVITIES

1 INTRODUCTION

43. This Annex describes the recommended procedures that should be used when assessing the nature and extent of impact in the water column from offshore oil and gas activities. These include assessment of contamination patterns, the rate and direction of any changes in those patterns, and of any biological effects in the water column. The strategy chosen is to a large extent based on results from the international BECPELAG workshop (Hylland et al., 2002a, b).

2 MONITORING STRATEGY

44. Different offshore development phases and activities, and local environmental conditions will demand different monitoring frequencies and survey strategies to be established. In general, two different approaches may be applied: near zone monitoring and wide area (regional) monitoring. Near zone monitoring of the water column requires measurement of effect at discrete points in water masses, only attainable through caging, whereas wider area or regional monitoring involves sampling larger areas.

45. For near zone effects monitoring in the water column there is normally no value in conducting baseline surveys prior to any petroleum development, especially when the strategy focuses on cage experiments. Baseline surveys may on the other hand be a valid part of regional trend monitoring programs on contaminant levels in pelagic fish.

Table 1. Overview of monitoring approaches.

approach	pro's	con's
Near zone monitoring (caging)	reflects local exposure (history); can use organisms with desirable properties (e.g. blue mussel)	"semi-natural" exposure situation; food availability unknown; limited to selected species;
Wider area monitoring (field sampling)	high ecological relevance	difficult to assess area integrated (but large); high natural variability (needs large sample numbers)

46. Particular attention should be paid to the OSPAR lists of relevant chemicals (OSPAR Convention, Annex 2, OSPAR Strategy with regard to Hazardous Substances, OSPAR List of Chemicals for Priority Action, OSPAR List of Substances/Compounds Liable to Cause Taint).

2.1 Near zone monitoring

47. Near zone monitoring should address spatial and temporal trends in contamination and effects within the impact zone of one field or installation (or a group of fields). Near zone monitoring should be based on the use of caged organisms. With current knowledge, the species of choice in the Northern Atlantic is the filter-feeding blue mussel and a common fish species, e.g. Atlantic cod. Future development may allow the exposure of more ecologically relevant, pelagic species or life-stages such as zooplankton or fish embryos. The main aim of near zone surveys is to quantify the area and/or volume of impact from a given installation or adjacent installations. Where applicable, the results can also be used to calibrate existing dispersal models.

2.2 Wider area (regional) monitoring

48. In order to put offshore industry installation impacts into a more holistic context, co-ordinated wider area (regional) surveys should be conducted. Such monitoring should describe general environmental background levels in addition to data from the near zone monitoring in the wider geographical area and should provide information on large-scale environmental patterns and enable the added effects of adjacent installations in areas of intense offshore activity to be assessed.

49. The wider area monitoring should describe general environmental levels distant from the installations and the integrated impact of offshore activities in a wider area. Regional monitoring should generally involve collecting selected fish species in regions close to offshore activities and in at least one reference area.

50. Regional monitoring will generally include impacts from both drilling and production activities. Effects from those two phases of oil field development can to some extent be separated by analysing fish with different life histories, i.e. demersal and more pelagic species. In all regional monitoring it is vital to assess migration patterns of the species chosen and expected residence time in the area being monitored. Biological effects need to be evaluated in view of their response time and their half-life.

3 TIMING

51. Near zone monitoring (caging) need to avoid the spawning period for the organisms involved, i.e. the spring. The survey should be performed during the months August, September or October.

52. As for near zone monitoring, the wider area surveys need to be performed a time outside the spawning period for the selected species. For the most common gadiids and flatfish, sampling should be performed during the autumn (August to October). An additional concern for wild-caught fish is migration patterns. Sampling should be done at a time when the chosen species is known not to have long migrations.

4 STATION POSITION PATTERN

53. Number of stations included and their positioning will depend on the local and regional conditions, and the purpose of the monitoring. Station positions for both near zone and wider area surveys should be determined on the basis of the expected transport and dilution of produced water components, preferably established through dispersion models.

4.1 Stations for near zone monitoring

54. The orientation and extent of the station pattern should be based on the predicted area of influence as determined by local dispersion modelling and discharge scenarios. If the aim is to assess possible gradients in impact radiating from a discharge point, a radial transect station design is most suitable. If a prevailing current direction exists, there should be a preponderance of stations in that direction. If the aim is to assess the degree of impact within an expected or predefined contaminated zone a set number of stations within and outside this area. There are statistical tools available that allow the estimation of the number of stations required for detecting a predefined difference in a measured parameter between impact and control zones with a certain statistical confidence. It is highly recommended that such analyses be considered in the planning of the surveys.

55. Adjustment of the station network for near zone monitoring may be required for one survey to another, if dispersion modelling is improved or predicts changes in the spatial extent of the concentration field.

4.2 Areas for wider area monitoring

56. Samples for the wider area monitoring should generally be collected using bottom trawl or pelagic trawl. Alternative methods are nets and cages. The method used must ensure the fish is alive when brought on board the ship. Any prior knowledge of migration behavior of the species chosen should be used to assess and determine the area the sampling will integrate over. A larger number of fish will need to be sampled and analysed in wider area compared to near zone monitoring. The number of fish required will need to be determined as indicated for near zone monitoring using previous knowledge of the variability in applied methods.

5 ANALYTICAL PROGRAMME

57. This chapter outlines recommended parameters, sampling procedures and analytical methods that should be implemented in point sampling monitoring of offshore discharge and impacts. Sampling equipment, sample collection, and treatment and storage of samples should be in accordance with the JAMP Guidelines for biological effects monitoring (Reference nos. 1997-07, 2003-10).

58. It is important to be aware that there is still limited knowledge of appropriate methods for water column monitoring. Any monitoring programme should therefore encourage testing of methods that are seen as promising for possible future inclusion.

59. Cage deployment in near zone surveys should be for at least 5-6 weeks.

5.1 Biological and chemical analyses of near zone collected and caged fish

60. Fifty individuals of the selected fish species should be deployed at each location. Twenty-five individuals should be analysed for each determinand. For comparison the same analyses should be performed on 25 individuals from the same population at the time of deployment (time 0 conditions).

61. In wider area monitoring, 25 individuals of the selected species should be collected by trawling in the region to be surveyed. At least three trawl hauls should be carried out at different locations within the region and approximately one-third of individuals should be sampled from each haul.

62. A minimum range of analyses (core methods) for caged fish are indicated in Table 2. In addition to contaminant-specific methods, the general health of the fish should be assessed (e.g. condition, liver somatic index). Gonad weight should always be determined.

63. Markers of PAH exposure (bile metabolites) and early effects, i.e. EROD and GST, should be determined alongside markers of damage (DNA adducts) and tissue change (histopathology). There are two reasons to include the methods indicated, one is to enable an assessment of the severity of effects, the second is to increase the ability to separate PAH-related effects to those caused by other factors. The methods should not be used in isolation.

Table 2. Core methods for caged fish.

Method	tissue/matrix	comment	method
EROD	liver		Stagg & McIntosh (1996)
GST	liver		Habig et al. (1974)
DNA damage	liver		Reichert et al. (2001)
Vitellogenin	blood plasma	blood sampled prior to and after deployment	Scott & Hylland (2002)
Histopathology	liver		to be added
ALA-D	red blood cells	if lead exposure is expected	Hylland (in press; 2003)
AChE	muscle		Bocquené & Galgani (1998)
PAH-metabolites	bile		GC or HPLC
metals (Cd, Hg, Pb)	liver		accredited analytical method

5.1.1 Sampling procedures

64. Each fish deployed should be marked/tagged, weighed and a blood sample taken prior to employment.

65. After the fish are captured it must be kept alive in saltwater tanks at the ship or sampled immediately. For every fish catch, necessary data about the sampling must be registered in a standardised sampling form; fish species, date, location (geographic co-ordinates), depth and gear.

66. Select a fish "at random". Anaesthetise the fish by a blow on the head.

- Take the blood from the ventral aspect of the tail (caudal vein) with a heparinised/aprotinised syringe. Withdraw 0.5-1.0 ml of blood. Transfer the blood to an eppendorf tube and put it on ice or in a cooling bag. For every 4th sample centrifuge the blood in an eppendorf centrifuge for 10 min. Transfer the plasma, using a glass pasteur pipette, to an appropriate vial and freeze it in liquid N₂. Determine fish length and weight. Examine the fish for parasites, sores etc., using the

ICES pathology codes. Open the visceral cavity carefully. Examine the organs for parasites, nodules, etc., using the ICES pathology codes.

- Take sample from the bile by using a 1 ml syringe with needle (0.5 x 20 mm). Withdraw as much bile as possible and remove the bile bladder without contaminating the liver. Transfer the bile to an appropriate vial and freeze it at -20°C.
- Carefully dissect out the liver, determine the weight and slice it in parts of approximate 1 g. Always use the same part of the liver for any given analysis.
- Dissect out the gonad.
- Determine the sex.
- Determine the weight.
- Open the brain and collect the otoliths, transfer them to an otolith envelope.

5.2 Biological and chemical analyses of caged mussels

67. One hundred and twenty blue mussels should be deployed at each location. The design of cages or nets must ensure that the deployment provides equal exposure of all individual mussels to surrounding water. Twenty individual mussels at each location should be analysed for each biological effects method. For PAH and metal analyses, three pools of 20 mussels each should be sampled. Samples should be taken from blue mussels from the same batch at the time of deployment (0-time samples; same number as in each cage).

68. The analyses required (core methods) are indicated in Table 3. In addition to contaminant-specific methods, the general health of the mussels should be assessed (condition).

Table 3. Core methods for caged blue mussel.

method	tissue/matrix	comment	method
BaPH	hepatopancreas		Michel et al. (1994)
AChE	hepatopancreas		Bocquené & Galgani (1998)
lysosomal stability	hematocytes		Lowe et al. (1995)
histopathology	hepatopancreas		to be added
PAH concentration*	whole mussel		accredited analytical method
lipid content	whole mussel		accredited analytical method
metals (Cd, Hg, Pb)	whole mussel		accredited analytical method

*the PAH-compounds to be analysed should be those on EPA's "list of 16 compounds". PAHs should be quantified by GC/MS according to JAMP Guideline Agreement 1999-01, Technical Annex 3. In some instances, total 2-6 ring parent and branched PAH analysis might be desirable. NPDs are the sum of naphthalene, phenanthrene/anthracene, dibenzothiophene and their C₁-C₃ alkyl-homologues.

5.2.1 Sampling procedures

69. After the blue mussels have been retrieved from cages they must kept alive in saltwater tanks at the ship or sampled immediately. Ensure that there is no local contamination of water used to hold the mussels (fumes, oil from pumps, etc).

70. At every location, necessary data about the sampling must be registered in a standardised sampling form; date, location (geographic co-ordinates), depth, water temperature.

71. Select an individual mussel "at random"

- Sample hemolymph from the adductor muscle using a syringe.
- Open the mussel by severing the adductor muscle. Allow internal water to drain off.
- The two gills and the digestive gland tissue are dissected (with scissors and scalpel), the style removed from the digestive gland by small pressure on the tissue and discarded.
- Gills and digestive gland should be transferred to appropriate vials and frozen in liquid nitrogen.

5.3 Supporting data

72. In both near zone and wider area surveys hydrographic data are required at each location (both deployment and retrieval) or trawling site. In addition to temperature, salinity and stratification, data on turbidity and phytoplankton biomass are useful for the interpretation of results. Additional components include the use of current meters and *in situ* fluorescence probes (PAH specific) with cages, logging data during the exposure period.

5.4 Statistical analyses

73. The response in individuals kept in cages at different locations (near zone surveys) or collected in different regions should be compared using analysis of variance (ANOVA). Observations need to be checked for homogenous variances (between groups) and, if necessary, transformed. If homogenous variances can not be achieved, non-parametric methods (Kruskal-Wallis) should be used. If a parametric ANOVA indicates significant differences between groups ($p \leq 0.05$), Tukey's post-hoc test should be used to identify differences between sites.

74. The proposed number of fish (25 individuals) or mussels (20 individuals) at each location/region are based partly on existing guidelines and partly on the known variability of the indicated methods in some species (Atlantic cod, blue mussel). The number of individuals may need to be revised according to specific objectives and accumulated knowledge of variability for each parameter for the species used.

5.5 Quality assurance

75. Internal and external (where available) quality assurance procedures for the indicated methods should always be documented. Detection limits for all analytical methods should be reported.

6 LITERATURE AND CITED REFERENCES

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Relevant web addresses

<http://www.niva.no/pelagic/web>

DEFINITIONS

Alkyl-decalines: These are isomers of decaline with one or many alkyl groups bonded to the basic structure. For example, C5 alkyl-decaline is a group of isomers with any of the following combinations: decaline with five methyl groups, decaline with three methyl and one ethyl group, decaline with one methyl and two ethyl groups, or decaline with a propyl- and an ethyl- group. Common to all of these isomers is a substitution to the decaline ring system of five carbon atoms.

Baseline Survey: The first investigation of environmental conditions performed in conjunction with the opening of a new area, or the survey performed for a field in prior to its development and start of its operational phase. A baseline survey is often carried out after exploratory drilling has been carried out and may therefore not provide an absolute baseline for the area.

C1-C3 alkyl homologues: These represent a group of isomers with substitutions to the aromatic ring system. Substitutions occur with a methyl- group (C1), with two methyl- or one ethyl- group (C2), and with three methyl- or one methyl- and one ethyl- group or one propyl- group (C3).

Chemical Contamination: This is indicated in an area if the levels of chemical constituents are significantly higher than the background levels for these constituents at the regional stations and reference stations in the region.

Monitoring Survey: A routine investigation of environmental conditions in a field or region conducted after operations (i.e. production drilling) have started.

NPD The sum of naphthalene, phenanthrene/anthracene, dibenzothiophene and their C₁-C₃ alkyl-homologues, considered to be indicative of petroleum derived aromatic hydrocarbons.

Radial Transect: A radial transect design consists of two axes placed perpendicular to one another with concentric circles placed at increasing distances away from the origin. A radial transect is a mapping system used to establish station distributions in association with a monitoring investigation. In this case, the radial transect is established with an installation at the origin the main axis in the prevailing direction of current flow, and the stations in the intersection between axes and circles.