INTERNATIONAL STANDARD

ISO 35103

First edition
2017-12

Petroleum and natural gas industries — Arctic operations — Environmental monitoring

Industries du pétrole et du gaz naturel — Opérations en Arctique - Surveillance de l'environnement

Reference number
ISO 35103:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 8, *Arctic operations*.

Introduction

General

This document has been developed in order to promote internationally agreed approaches to environmental monitoring of oil and gas operations in Arctic offshore environments. The monitoring of onshore environments is not included in this document, except where relevant to an offshore development.

Environmental monitoring

Environmental monitoring includes:

a) monitoring of environmental aspects for normal, abnormal and emergency conditions:

   The environmental aspects of an organization under all conditions are determined by its environmental management system (EMS) procedures and can include:

   1) emissions to air;
   2) releases to water;
   3) releases to land;
   4) use of raw materials and natural resources, including physical presence of facilities;
   5) use of energy;
   6) energy emitted, including heat, radiation, vibration, noise and light;
   7) generation of waste and/or by-products;
   8) environmental aspects with beneficial impact;

b) monitoring of environmental impacts:

   Environmental impacts can occur at local, regional and global scales, while they can also be direct, indirect or cumulative.

The relationship between environmental aspects and environmental impacts is one of cause and effect.

Within the scope of this document, the environment includes all relevant physical, chemical and biological components of the sea, atmosphere and land, where the latter is potentially impacted by an offshore development. When an organization determines the scope of its environmental impact, the need to protect the following attributes is considered:

— human beings and cultural heritage;
— fauna and flora;
— soil, water, air and climate;
— material assets (such as existing pipelines and cables, shipping routes, seabed resources and resource extraction facilities).

There are no existing internationally agreed standards for environmental monitoring; neither are there such standards for marine environmental monitoring although there is a considerable body of guidance documents.

This document presents sufficient information to guide organizations towards relevant monitoring methods for use in the Arctic.

The special conditions of the Arctic will require organizations to modify their monitoring methods to suit the conditions encountered.

General marine monitoring methods can be adapted by the oil and gas sector to meet the needs of its Arctic maritime locations, its development phases, facility types and operations, their environmental aspects and their impacts upon the marine environment.

Relationship of this document to ISO 14001, ISO 9001 and other standards

The organizations that have implemented ISO 14001 or ISO 9001 already apply the elements of monitoring, measurement, analysis and improvement to their (environmental) monitoring processes.

Additional standards that apply to environmental monitoring include laboratory standards, specific guides on sediment, water and air quality monitoring, and recommended practices for species identification; the use of agreed statistical methods is essential.

Petroleum and natural gas industries — Arctic operations — Environmental monitoring

1 Scope

This document gives requirements, specifications and guidelines to ensure that environmental monitoring in the offshore Arctic region is fit for purpose. The Arctic region includes the territory lying to the North of the Arctic Circle (Latitude 66°33′45.8″). This document can be applied to sub-Arctic locations which experience Arctic-like conditions and contain relevant components of a cold-climate ecosystem.

This document is applicable to all Arctic oil and gas operations from licence block acquisition through exploration, engineering design, construction, commissioning, operation, decommissioning and restoration. It covers the offshore or maritime environment, including for the purposes of this document, the fully marine and estuarine waters of the Arctic, whether frozen or ice-free. The environment includes all relevant physical, chemical and biological components. Monitoring methods for onshore (terrestrial) environments are not covered in this document, although onshore environments are included where monitoring is required at onshore locations in relation to an offshore development.

This document covers both monitoring of environmental aspects for normal, abnormal and emergency conditions, and monitoring of environmental impacts. It includes monitoring in near-field, far-field, transboundary and regional scales, but does not include global environmental monitoring.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/TS 20281, *Water quality — Guidance on statistical interpretation of ecotoxicity data*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Risk

3.1.1
accident
unplanned event that resulted in injury or ill health of people, or damage or loss to property, plant, materials or the environment or a loss of business opportunity

3.1.2
emergency
unplanned event that has caused injury, loss or damage or that is an actual or potential threat to human life, the environment or the installation and has made it necessary to deviate from the planned operation or suspend the use of standard operating procedures

3.1.3
hazard
physical situation with a potential for causing human injury, damage to property, negative effects on the environment or a combination of these

3.1.4
hazard identification
process of recognizing that a *hazard* (3.1.3) exists or has the potential to exist and defining its characteristics

3.1.5
incident
event or chain of events which has caused or could have caused injury, illness, and/or damage (loss) to assets, the environment or third parties

[SOURCE: OGP Glossary of HSE Terms]

3.1.6
risk
product of the chance that a specified undesired event will occur and the severity of the consequences of this event

Note 1 to entry: Also defined as the measure of the likelihood of occurrence of an undesirable event and of the potentially adverse consequences which this event can have upon people, the environment or economic resources.

[SOURCE: OGP Glossary of HSE Terms]

3.1.7
risk assessment
whole process of *risk* (3.1.6) analysis and the evaluation of the results of the risk analysis against technological and/or economic, social and political criteria

[SOURCE: OGP Glossary of HSE Terms]

3.2 Geography

3.2.1
Arctic
territory lying to the North of the Arctic Circle (Latitude 66°33′45.8″)

3.2.2
region
delimited area of the continental shelf defined by geographical coordinates

3.3 Survey

3.3.1
baseline survey
environmental survey of an area or locality to obtain information on its physical, chemical and/or biological status before a new activity starts

3.3.2
grid
design used to determine locations for the sampling stations if the position of the oil/gas field has not yet been established or if obstacles on the seabed make it impossible to use a *radial transect* (3.3.4) design

[SOURCE: Norwegian Environment Agency. Environmental monitoring of petroleum activities on the Norwegian continental shelf. M408, 2015]

3.3.3
transect
straight line through a natural feature along which observations are made or measurements taken

3.3.4
radial transect
design consisting of two axes placed perpendicular to one another with an offshore installation at the origin and the main axis in the prevailing direction of current flow

3.3.5
remotely operated vehicle
remotely controlled underwater vehicle carrying a video camera, which is often equipped with sonar, sensors, a manipulator and sampling devices

3.3.6
water column
marine environment from the water surface to the surface of the sediment

3.3.7
pelagic
relating to the marine *water column* (3.3.6)

3.4 Biology

3.4.1
benthic
relating to the marine zone on, within or near the seabed

3.4.2
biota
living organisms in a given location

3.4.3
epifauna
animals that live on a surface, such as the sea floor, other organisms, or objects, or an ice surface

3.4.4
epiflora
plants that live on a surface, such as the sea floor, other organisms, or object, or an ice surface

3.4.5
macrofauna
organisms larger than 1,0 mm (i.e. that are retained on a 1,0 mm sieve)

3.4.6
meiofauna
organisms smaller than *macrofauna* (3.4.5), but larger than *microfauna* (3.4.7)

Note 1 to entry: Meiofauna generally refers to specific groups of organisms (foraminifera, nematodes, harpacticoid copepods, etc.).

3.4.7
microfauna
microscopic animals

3.4.8
plankton
organisms that spend all or part of their life cycle floating or drifting in the water and that have little or no independent mobility

Note 1 to entry: Plankton comprises plants (phytoplankton) and animals (zooplankton), and includes seasonally the juvenile stages of larger marine animals.

3.5 Oil and gas

3.5.1
drill cutting
rock piece dislodged during drilling

Note 1 to entry: Drill cuttings from offshore wells contaminated with adhering residual drilling fluid are often discharged to sea. Drilling fluid is a mixture of liquids and solids pumped into a borehole during drilling for the purpose of cooling and lubricating the drill string, transporting drill cuttings to surface, maintaining borehole stability and preventing hydrocarbon influx.

3.5.2
produced water
water (generally brine) brought up from the hydrocarbon-bearing strata during the extraction of oil and gas, including formation water, injection water, and any chemicals added downhole or during the oil/water separation process

[SOURCE: IOGP Environmental Performance Indicators — 2014 data]

3.6 Environment

3.6.1
background level
concentration of selected parameters (hydrocarbons, metals, radioactive substances, etc.) that provide a level as close as possible to the natural concentrations in the area and to determine natural conditions and a level prior to project activities

Note 1 to entry: Background level can include existing anthropogenic contamination.

[SOURCE: Fishery Harbour Manual on the Prevention of Pollution — Bay of Bengal Programme, Food and Agriculture Organization of the United Nations (FAO), Fisheries & Aquacultures Department, 1999]

3.6.2
environmental aspect
element of an organization's activities or products or services that interacts or can interact with the environment

[SOURCE: ISO 14001:2015, 3.2.2, modified – notes to entry have been omitted.]

3.6.3
environmental impact
change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's *environmental aspects* (3.6.2)

[SOURCE: ISO 14001:2015, 3.2.4]

3.6.4
environmental impact assessment
tool used to identify the *environmental impacts* (3.6.3) of a project prior to decision-making

3.6.5
monitoring
systematic measurement of variables over time to establish their current state and variation as well as a baseline

3.6.6
strategic environmental assessment
systematic process for evaluating the environmental consequences of a proposed policy, plan or programme initiative in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations

Note 1 to entry: The SEA processes and objectives are framed by the SEA Protocol to the UN Convention on *environmental impact* (3.6.3) assessment in the transboundary context (the Espoo Convention).

4 Abbreviated terms

ASTM	American Society for Testing and Materials
AUV	autonomous underwater vehicle
EIA	environmental impact assessment
EMP	environmental monitoring programme
EMS	environmental management system
FAO	Food and Agriculture Organization (of the United Nations)
GOST	Gosudarstvennyy standart, technical standards maintained by the Euro-Asian Council for Standardization, Metrology and Certification (EASC), a regional standards organization operating under the auspices of the Commonwealth of Independent States
ICES	International Council for the Exploration of the Sea
IOGP	International Association of Oil and Gas Producers
JAMP	Joint Assessment and Monitoring Programme (of OSPAR)
NS	Norwegian Standard
OGP	International Association of Oil and Gas Producers (now IOGP)
OSPAR	Oslo and Paris Commission
ROV	remotely operated vehicle
SEA	strategic environmental assessment
USEPA	United States Environmental Protection Agency
WMO	World Meteorological Organization

5 General requirements for environmental monitoring

5.1 Application of ISO management system standards

The organization shall document their environmental monitoring and compliance methods. For this purpose, the organization can use ISO 14001 that sets out requirements to enable organizations to manage their environmental aspects and associated impacts.

NOTE The general requirements for environmental monitoring are described in ISO 14001:2015, 9.1.1 (monitoring, measurement, analysis and evaluation) and in ISO 14001:2015, 9.1.2 (evaluation of compliance).

ISO 14031 provides guidance for organizations in environmental performance evaluation, including the use of indicators, which can also be applied to environmental monitoring results.

5.2 Objectives of environmental monitoring

The objectives of environmental monitoring can include one or more of the following:

— assessing compliance with regulatory requirements;

— providing data against which short- and long-term environmental impacts can be determined;

— tracking the performance of a project or operation and the effectiveness of control, mitigation or remediation measures;

— verifying those environmental impacts predicted in the EIA;

— alerting operators to take remedial action, if unforeseen or unacceptable impacts arise;

— providing data to facilitate environmental audit of an organization or facility.

The objectives of an EMP shall be agreed with relevant parties and shall be clearly stated in the programme description. The objectives may vary depending upon those organizations that have an influence on the monitoring programme content.

5.3 Specification for monitoring

Monitoring requirements can be decided by:

— supervisory bodies;

— oil and gas operating companies;

— lenders;

— investors.

Monitoring requirements can be influenced by:

— joint venture partners;

— local communities;

— non-governmental organizations;

— research institutes.

The supervisory body normally presents monitoring requirements in statutory documents including licences, permits, consents, authorizations and their associated conditions. Monitoring requirements can also be presented in the EIA submitted to the supervisory body.

The organization can have its own monitoring requirements in addition to those of the supervisory body. Similarly, joint venture partners can influence the operating company to include specific monitoring requirements.

The investment and insurance sectors can require monitoring and reporting as part of their environmental and social safeguard principles, and as a condition of their loan agreements.

Formal agreements can be made with or on behalf of:

— local residents;

— government bodies;

— environmental non-governmental organizations;

— organizations with commercial or other interests in the location of operations.

Local communities and other interested parties that can be affected by proposed activities can participate in the design and implementation of monitoring activities, the scope of which can be broader than environmental monitoring, including, for example, relevant social and health issues.

The organization shall consider all environmental monitoring requirements in its EMP.

5.4 Planning a monitoring programme

5.4.1 Programme specification

The EMP shall be managed as part of the environmental or quality management system of the organization. The EMP shall be prepared by the organization's experts under the authority of the appropriate manager.

The EMP shall specify:

a) monitoring objectives;

b) requirements of the programme specified by the regulators, the organization (e.g. in an EIA) or other parties including the limits to be achieved (e.g. volumes or concentrations);

c) monitoring methods;

d) facilities to which it applies and a description of the activities that could cause environmental impact;

e) geographical location to which it applies;

f) duration and geographical extent of monitoring;

g) environmental components within the scope (e.g. water, air, sediment, flora and fauna) and indicator variables within each component;

h) sampling requirements and analytical methods, including statistical requirements, for environmental aspects and environmental impacts, and including details on frequency of sampling and sample size needed to meet study objectives, as well as on preservation and storage of samples and other quality assurance requirements;

i) controlled parameters (aspects) and regularity of monitoring thereof;

j) location of monitoring stations;

k) supporting information to be collected (e.g. meteorological, hydrographical or hydrological data);

l) reporting requirements;

m) competence requirements for personnel involved in all parts of the monitoring programme.

Where specialized contractor companies are to be employed for monitoring, information shall be specified to enable the contractor to conduct the sampling and analysis to the standard required.

5.4.2 Programme adjustment

The EMP may be amended in terms of sampling frequency and extent in the event that results indicate the need for more or less frequent sampling or the need for a wider or more limited sampling extent, provided the objectives and regulatory requirements for the programme can still be met in full.

5.4.3 Action on non-compliance

The EMP shall make reference to the organization's EMS procedures for non-compliance with regulatory or other limits.

5.5 Spatial scales

5.5.1 General

Environmental monitoring can be conducted on a number of scales, namely near-field, far-field, regional or transboundary scale.

5.5.2 Near-field

The near-field scale shall be considered to include the area adjacent to a facility, in which environmental impacts are measurable in excess of background levels. Within this location, there is a mixing zone for emissions and discharges where initial dilution takes place.

5.5.3 Far-field

The far-field scale shall be considered to include locations away from the immediate vicinity of a facility to which emissions or discharges can be dispersed or transported.

5.5.4 Regional

Regional monitoring may also be considered for large regional geographic features, such as an entire sea area. Such monitoring should be planned to monitor large-scale changes due to variation in natural conditions and to differentiate between natural variations and impacts from industrial activities.

Regional monitoring may be conducted by authorized governmental bodies in accordance with their competence, as well as non-governmental organizations. Joint industry programmes or other collaborative mechanism can also be used to enhance regional data collection. Baseline data at regional level may be published in an SEA.

5.5.5 Transboundary

Environmental monitoring should address the likelihood of environmental impacts (e.g. contamination) being transferred across one or more national boundaries.

5.6 Temporal scales

5.6.1 Design

Environmental aspects (e.g. discharges and emissions) and environmental impacts can vary widely with time. The design of the EMP shall give due consideration to the temporal variations of industrial inputs and impacts of environmental variables.

The duration of the EMP and frequency of sampling should take into account the expected timescale of the operation, which can be short term (e.g. in the case of a single discharge) or long term (e.g. in the case of lifetime monitoring of a facility).

5.6.2 Variation in environmental aspects

The sampling programme for environmental aspects shall take into account all known variations associated with each environmental aspect in order to ensure representative sampling.

5.6.3 Natural fluctuations

The EMP shall take into account the natural variation in the physical, chemical and biological properties of the marine environment. This natural variation can be on a scale of diurnal, seasonal or long-term trends.

5.7 Environmental aspects

5.7.1 Types of environmental aspects

Environmental monitoring shall be established by the organization for those significant environmental aspects over which it has control. These environmental aspects shall include:

a) emissions to air;

b) releases to water;

c) releases to land;

d) use of raw materials and natural resources;

e) use of energy;

f) energy emitted, heat, radiation, vibration (noise) and light;

g) generation of waste and/or by-products;

h) environmental aspects with beneficial impact.

Significant environmental aspects shall be maintained in the organization's EMS and shall be included in the organization's environmental report.

NOTE Determination of significant environmental aspects is described in ISO 14001:2015, 6.1.2.

5.7.2 Normal, abnormal and emergency conditions

Monitoring of environmental aspects shall describe normal conditions that include the stable operating mode for a facility or an activity.

The EMP should describe options for possible extension to include potential impacts from:

— abnormal conditions that include events that are not part of the stable operating mode, for example, start up or shut down of facilities, whether planned or unplanned;

— emergency situations that include those situations where there has been a loss of control or of containment by the organization of an environmental aspect. Emergency events include uncontrolled spillage, or release of product, or other accidents with environmental consequences or negative impact on local residents' health.

5.7.3 Control aspect in response to monitoring

The organization shall consider the action it should take in the event that monitoring detects:

a) an environmental aspect that is outside of its required or expected range;

b) an environmental impact that is greater or lesser than predicted.

The action can result in adjustments being made to the operating conditions or to the EMP.

5.8 Environments and components

Environmental monitoring shall take into account the variety of environments that can be impacted by facilities. These can include land, sea and air, and the components of each of these, such as:

— land: soil, surface water, groundwater;

— sea: bottom substrates, water column and ice;

— air: ground level, troposphere.

Additional sub-components, such as surface and subsurface layers and interfaces, shall be considered when identifying sampling requirements.

5.9 Baseline conditions

Baseline conditions represent the environmental conditions that pertain prior to the existence of a facility or activity. In establishing an EMP, the organization shall establish the baseline conditions for each parameter that is to be included in the EMP. The following shall be taken into account when establishing baseline conditions:

a) regulatory requirements;

b) temporal and spatial extent of natural variations;

c) existing impacts from other facilities.

The supervisory bodies and other organizations can collate baseline data within a regional scale SEA or within regional databases.

5.10 Parameters

5.10.1 Selection of parameters

The organization(s) responsible for environmental monitoring should consider in advance the parameters to be measured in order to quantify those environmental aspects and environmental impacts that are to be included in the EMP. These can include physical, chemical and biological characteristics of the environment and human communities, and interactions between the characteristics, and their natural variations. The parameters shall be selected on the basis of the likelihood of significant environmental impacts as a result of the organization's significant environmental aspects.

The decision to include each parameter should generally be related to the risk of a significant environmental impact and its value as an indicator of impact. The means of determining significance shall be included in the organization’s EMS documentation.

5.10.2 Accuracy

The principles of ISO 5725-1 may be applied to environmental monitoring parameters.

Accuracy applies also to position fixing for sampling locations. All sampling positions shall have positions documented using global positioning by satellite navigation, or range positioning using suitable landmarks.

5.10.3 Detection limits

Detection limits or limit of quantification shall be established and specified for each parameter included in an EMP.

5.10.4 Units and other specifications

Where countries or parties using this document use different units of measurement, conversion factors should be agreed between the parties to whom the results are to be reported.

5.10.5 Physical parameters

Physical attributes of the environment can be affected by environmental aspects. The effects can vary in scale and significance. Appropriate measurements should be made in those cases where physical changes are foreseen by the organization. Examples include landscape changes, erosion and deposition, sinkholes, temperature of water, air or sediment, noise and light, radiation, and the exclusion of the public on the grounds of safety or security.

Physical attributes should be sampled and analysed using nationally approved or internationally agreed methods.

The design of a physical monitoring programme shall consider:

a) natural variations in physical conditions;

b) extent to which modification of physical conditions can be attributed to environmental impacts;

c) time and spatial scales over which modification to physical conditions can take place.

5.10.6 Chemical parameters

Chemicals released in emissions, discharges and wastes can be distributed in the environment via dispersion pathways; they can undergo changes in chemical composition as a result of physical, chemical and biological processes. Based upon environmental aspects that are assessed as being significant aspects (see 5.7.1), the organization should identify those elements and compounds that are to be analysed.

Chemical attributes should be sampled and analysed using nationally approved or internationally agreed methods.

The design of a chemical monitoring programme shall consider:

a) natural variations in chemical concentrations;

b) extent to which chemical concentrations can be attributed to environmental impacts;

c) definition of significant contamination based on statistical analysis of regional reference sampling locations;

d) whether compounds introduced to the environment are subject to physical, chemical or biological modification and the timescale over which such modification can take place.

5.10.7 Biological parameters

Environmental aspects can affect attributes of the biological community at the location of the facility or activity. Environmental impacts can include elimination of species in the immediate location (e.g.

by smothering), changes in the numbers or distribution of species (biodiversity and introduction of invasive species), the accumulation of chemicals and radiation in biological tissues, impairment of functions, such as reproduction, biological indicators of effect and exposure, and behavioural effects.

Accurate identification is essential for the determination of species in all environments. The organization shall determine the taxonomic level to which flora and fauna identification will be carried out in order to meet the monitoring objectives.

Taxonomic experts can be required in order to identify specimens. The organization shall ensure that there is a source of competent experts available for the identification of species.

Biological attributes shall be sampled and analysed using nationally approved or internationally agreed methods.

The design of a biological monitoring programme shall consider:

a) natural spatial variations in biological populations including near-field, far-field and regional sampling locations; natural diurnal, seasonal, inter-annual and long-term temporal variations;

b) extent to which a biological effect can be attributed to an environmental aspect at population levels;

c) likelihood of lethal or sub-lethal effects;

d) whether effects can be acute or chronic;

e) possibility of bioaccumulation leading to the presence of residues in biological tissues; redistribution of residues by biological mechanisms; bio-magnification in the food chain;

f) biodegradation of compounds;

g) critical paths for residues including species of interest (target species) owing to their presence in the food chain, including species used for human food from hunting and fishing activities.

5.10.8 Associated measurements

When conducting monitoring, sufficient associated data should be collected to aid interpretation of results. Associated data include all those parameters that can be related to the target parameter. They can include:

— hydrography: bathymetry, tides, sediment (granulometry, organic content);

— hydrology: depth, conductivity, salinity, temperature, pH, flow rates, current speed and direction, ice conditions, storm surges, hydrometry;

— meteorology: wind speed and direction, temperature, humidity.

The organization shall identify the associated measurements that are to be made to support interpretation of the results of their monitoring programmes, and include such measurements, including sampling depth and locations, in the specification for the EMP.

5.10.9 Position fixing

All sampling locations shall be documented including position (coordinates), date and time.

5.11 Modelling

The organization should consider the use of modelling (e.g. dispersion modelling) of land, sea and air environments in order to examine transport paths for contaminants and to provide the basis for the selection of sampling stations.

The organization should use nationally approved models, where available, or should agree in the appropriate model in advance with the supervisory body.

5.12 Sampling

Sampling design is critical in ensuring that data are sufficient to draw the necessary conclusions.

Sampling is concerned with the selection of a subset from within a population in order to determine the characteristics of the whole population.

The organization shall develop a sampling strategy appropriate to the statistical population, in accordance with nationally approved standards or regulatory requirements. The sampling strategy shall be appropriate to the study objectives, the regulatory requirements, the characteristics of the environmental aspect, and the location and extent of the potential environmental impact.

Sampling shall be informed by statistical design such that sufficient statistical power is achieved to reach valid conclusions.

The organization shall include sufficient information on sampling to guide relevant staff in the taking, treatment, preservation and retention time for samples and sub-samples.

5.13 Analytical methods

The organization shall require laboratories to adopt nationally approved or internationally agreed methods for the analysis of physical, chemical and biological materials.

The organization shall require laboratories participating in the analysis of environmental samples to state the analytical methods that are to be used.

Where no international or national standard methods are available, the organization shall use methods that are approved by the supervisory body. Alternatively, the best available method based on scientific judgement shall be selected and its use documented.

Laboratories, including those used for analysing samples, shall comply with the requirements of ISO/IEC 17025.

5.14 Toxicity tests

In conducting toxicity tests, the organization shall adopt nationally approved or internationally agreed standards.

5.15 Statistical methods

The organization shall state in advance the statistical methods that are to be applied to monitoring, including methods for laboratory tests and for the analysis of physical, chemical and biological data.

The statistical methods used for laboratory and field data shall follow nationally approved or internationally agreed methods.

5.16 Costs of monitoring

The organization should forecast and maintain data on costs of its EMPs. The organization can be guided by ISO 19008.

5.17 Environmental monitoring report

The organization shall prepare the required reports on environmental monitoring of its facilities or activities.

Environmental monitoring data prepared in accordance with ISO 14031 may be used in environmental reporting.

The organizations shall specify the format for reporting and distributing the results of monitoring.

6 Factors to be considered for Arctic offshore environments

6.1 Characteristics of the Arctic

When designing and implementing an EMP for Arctic offshore environments, the organization shall adopt the general requirements as described in Clause 5 and shall take into account the specific nature of the location, including:

a) polar location, high latitude;

b) low temperatures;

c) seasonal characteristics;

d) ice environments;

e) endemic species;

f) human communities.

When designing an EMP, the existing international marine monitoring plans of the Arctic nations shall be consulted. The organization may integrate its monitoring plans in the interests of efficiency. The relevance of monitoring and scientific studies at a local, national or international level should be considered in relation to programme design.

The organization shall consider the need for appropriate Arctic expertise and appropriate subject matter experts in designing and implementing its EMP.

6.2 Polar location

6.2.1 Remoteness

The Arctic is sparsely populated and remote from cities and infrastructure. The potential consequences of operating at high latitudes should be considered using appropriate risk assessment procedures.

6.2.2 Positioning

Position fixing methodology for environmental monitoring surveys shall consider potential challenges associated with high latitudes, e.g. adequacy of surveys, mapping, magnetic and gyro-compasses, and shall be agreed with the appropriate supervisory body.

6.2.3 Day/night cycle

The 24 h polar night and polar day have consequences for maritime sampling surveys and for biological monitoring.

The ability to fix accurate positions and to work safely can be affected by day/night cycles. In planning sampling surveys, the organization shall assess the risks associated with polar day/night cycles.

Daily and seasonal biological cycles are affected by the polar day/night cycle. Examples are primary and secondary production of plankton populations. Sampling strategies for biological populations shall take into account the diurnal, seasonal and other biological cycles encountered in the Arctic.

6.3 Low temperatures

Methods used for environmental monitoring shall take into account the low temperatures encountered in the Arctic. Monitoring equipment, including power sources, meters and camera equipment, shall be capable of calibration and sustained operation in low temperature environments.

The effects of heated water discharges on ambient water temperature, local ice formation and ice forms shall be considered.

6.4 Seasonal characteristics

Seasons in the Arctic are typically dominated by long winters and short summers, with spring and autumn each lasting in the order of only a few weeks. Arctic seasonal aspects shall be taken into account when designing environmental monitoring with respect to offshore oil and gas developments.

6.5 Ice environments

Ice is not uniformly present in Arctic marine environments and it exists in many forms. The presence or absence of ice, whether permanent or temporary, including permafrost below the sea floor, shall be taken into account when designing offshore EMPs. In the absence of specific methods, up-to-date reference texts should be consulted. New strategies and technologies should be considered, evaluated or developed that are capable of collecting information under ice. These methods may include autonomous systems, moorings and remote sensing.

The presence of ice environments onshore, including permafrost and glacial ice, shall be taken into account when designing environmental monitoring with respect to offshore developments.

ISO 35106 provides requirements for metocean, ice and seabed data. Standard WMO terminology should be adopted in referring to sea ice.

EMPs shall take into account the likely extent of sea ice during implementation of the programme and the consequences for the sampling locations.

EMPs shall be sufficiently flexible, to accommodate the presence or absence of ice. Where sampling sites are inaccessible, the closest possible alternative site shall be selected and its coordinates documented.

Where environmental monitoring includes the ice edge, methods for sampling shall be harmonized with national sampling programmes.

Sampling of sea ice, in all its forms, for physical, chemical or biological attributes, shall use nationally approved or internationally agreed standards. Where no such standards exist, sampling should adopt best scientific and technical practice and methods shall be documented.

Special methods should be considered for sampling snow cover over ice and for ice underlying snow. In particular, the EMP should consider methods for estimating the deposition of black carbon on snow and ice, and adopt current best practice.

6.6 Endemic species

6.6.1 General

The Arctic Ocean contains unique life forms that are specifically adapted in their life cycles, ecology and physiology to Arctic conditions. These endemic species vary from the microscopic planktonic species, through benthic and pelagic species, to large sea mammals. EMPs shall consider the need to include all Arctic trophic levels from primary producers to top predators.

Sampling and extraction methods shall be designed to collect, if required, microfauna, meiofauna and macrofauna, including the biota attached to surfaces, i.e. the epifauna and epiflora.

Programme design shall consider migration routes, reproductive behaviour and feeding, spawning and nursery grounds and presence of invasive species.

In assessing the significant impacts of an oil and gas operation, the near-field, far-field and regional aspects of biological populations shall be considered.

6.6.2 Identification

Identification of Arctic specimens to species level shall be carried out when possible; otherwise, the most practical taxonomic level shall be documented.

Where there are uncertainties about specimen identification, appropriate experts on Arctic taxonomy shall be consulted.

6.6.3 Ice flora and fauna

In the absence of standardized methods for the sampling of Arctic ice flora and fauna, field techniques shall be based upon best scientific and technical practice and shall be documented.

6.7 Human communities

6.7.1 General

The Arctic is one of the most sparsely populated regions in the world. However, the local communities should be involved in designing and implementing EMPs. Special attention should be paid to consultation with indigenous peoples.

6.7.2 Indigenous peoples

The indigenous peoples of the Arctic maintain lifestyles that are based upon traditional hunting, gathering and fishing methods. Decisions on Arctic oil and gas operations can affect indigenous lifestyles.

The role and contribution of indigenous peoples and traditional knowledge shall be considered and documented in the design and execution of the EMP.

Many Arctic communities rely upon subsistence food sources, which can contain a range of contaminants. EMPs should reflect local subsistence food use patterns.

EMPs shall consider the potential impacts of Arctic operations upon the traditional lifestyles, population, morbidity, health and welfare of indigenous peoples.

6.7.3 Local and traditional knowledge

The extent to which local and traditional or indigenous knowledge can be incorporated into scientific EMPs should be considered in consultation with appropriate experts.

7 Monitoring requirements for offshore oil and gas sector in the Arctic

7.1 General

The offshore oil and gas sector has specific environmental monitoring requirements owing to its distinctive environmental aspects during different developmental phases and the maritime location of its activities.

The operator shall define the environmental monitoring required for each phase of development in the Arctic.

7.2 Offshore life cycle phases

The development phases for offshore oil and gas fields include:

a) pre-operations, including licence acquisition and planning;

b) exploration, including seismic, site surveys and exploration and appraisal drilling;

c) engineering design;

d) construction;

e) installation;

f) commissioning;

g) production operations, facilities and pipeline operation and maintenance;

h) decommissioning and facility removal;

i) site restoration;

j) logistics, air and sea transport and accommodation associated with each phase.

Each developmental phase can require a different monitoring strategy. Guidance on monitoring during offshore development can be found in various sources as listed in the Bibliography.

7.3 Offshore environmental monitoring programme design

7.3.1 Objectives of offshore environmental monitoring

The purpose of offshore environmental monitoring is to achieve the general objectives of environmental monitoring (see 5.2) for the oil and gas sector in the Arctic maritime area, taking into account the near-field, far-field, regional and transboundary scales of potential impact.

7.3.2 General aspects of environmental monitoring programme

The operator is responsible for establishing EMPs that meet the relevant regulations of the Arctic state in which operations are conducted, their associated guidelines on marine environmental sampling and the requirements of this document. The operator shall give due regard to the interests of adjacent Arctic states, including potential transboundary impacts.

EMPs shall also incorporate monitoring that has been agreed as part of the EIA process, including input from Arctic indigenous peoples and settled communities.

The comparability of data derived from oil and gas monitoring in other Arctic states shall be considered during EMP design.

The duration of the EMP for Arctic oil and gas operations shall take into account the expected timescale of the operation, which can be short term (e.g. in the case of a seismic survey or an exploration well) or long term (e.g. in the case of lifetime monitoring of an offshore production facility).

For remote Arctic locations, the type and specification of vessels and/or aircraft and the associated equipment required to conduct the monitoring should be considered during programme planning.

If the results of environmental monitoring differ from predicted effects or if unforeseen trends in contamination or effects occur, studies shall be conducted to determine the reasons. Monitoring results shall be discussed with the supervisory body. The EMP findings can be used to propose modification of the future programme.

7.3.3 Offshore environmental aspect and environmental impact identification

At each phase, appropriate risk assessments shall be carried out to determine the significant environmental aspects and environmental impacts of the operator's normal, abnormal and emergency situations, including accidents and incidents with potential environmental consequences that should be included in the EMP.

Significant environmental aspects (see 5.7) and environmental impacts shall be determined for each of the development phases for oil and gas developments and the supporting activities that are within the scope of the offshore development.

Environmental risk assessment shall identify and consider all potential environmental impacts at each development phase of oil and gas and shall ensure that those impacts that are judged to be significant are included in the EMP.

The identification of significant environmental aspects for each oil and gas development phase shall take into account the specific Arctic characteristics of the development location.

In the Arctic, particular attention shall be given to the risk of spills of oil or chemicals in ice-prone waters. The need for post-spill surveillance and monitoring, which may include monitoring under ice, shall be considered in operator and authority contingency plans.

7.3.4 Sampling and analysis

Conventional marine sampling equipment is generally used for sediments and water column in Arctic conditions. The sampling equipment used for environmental monitoring in the Arctic shall be specified prior to surveys and shall be documented in monitoring reports. Conventional sample storage, preparation and analysis are used for Arctic samples. Any modifications to equipment or methods to meet Arctic conditions shall be documented.

The statistical analysis of Arctic offshore physical, chemical and biological parameters shall follow standard marine methods.

Considerations shall include the need for collecting baseline information prior to operations as specified by supervisory bodies or other parties.

If available, existing Arctic data sets shall be obtained and used to support the baseline description.

To the extent possible, sampling sites for water and sediments that are established for baseline data collection shall be used for future sampling.

Gaseous emissions from exhausts, flaring and venting are included in operational and environmental monitoring. There is typically no requirement for air quality monitoring at offshore sites. Air quality monitoring can be required at nearby ice-bound, landfast ice or onshore environments, where modelling suggests that air quality standards can be at risk from offshore emissions. The operator should consider sampling for air quality parameters in cases where emissions can be expected to impact land or ice surfaces.

For certain parameters, the use of automated monitoring systems for selected parameters should be considered in addition to or instead of physical sampling.

7.3.5 Reference sampling

Reference stations shall be located in areas that are not expected to be affected by discharges, effluents and emissions or other environmental aspects of the oil and gas sector and shall be representative of the physical parameters and the chemical and biological baseline.

Analysis of Arctic background station results shall consider the influence of:

a) widespread elevation of contaminants arising from global or regional air streams or oceanic currents;

b) local elevation of hydrocarbon from natural seeps; elevation of metals from local geochemical conditions;

c) the natural variability in space and time of Arctic biota.

To the extent possible, background sampling stations should be in locations that have physical, chemical and biological characteristics of seabed, water column and air that are similar to those of the field specific stations in the vicinity of oil and gas installations.

7.3.6 Near-field sampling

As well as general conditions for the layout of sampling sites, transects or grids around offshore installations, the practicality of regularly sampling different marine environments under Arctic conditions shall be taken into account. Survey procedures shall consider the possibility of temporary ice cover and the action to be taken in the event that sampling sites are inaccessible.

Near-field sampling should concentrate on detecting both acute and chronic impacts on water quality, sediments and biota. The potential impacts of contaminants from nearby or future facilities should be considered.

Visual surveys of benthic habitats are carried out using a remotely operated vehicle (ROV), autonomous underwater vehicles (AUV) or towed video system. Side-scan sonar or other non-invasive technologies may be used to determine the material and texture of the seabed. Visual surveys should be carried out using either a radial transect design or a grid design. Visual surveys should be able to detect debris and gross disturbance resulting from drilling operations or drilling rig anchoring.

Typically, near-field sampling will include the detection and biological effects of:

a) drill cutting discharges on the seabed and the local formation of cuttings piles;

b) produced water discharges to sea, including dilution, dispersion and localized effects of temperature, density, chemical, radiation and hydrocarbon constituents; the temperature profile and stratification of the receiving water should be determined;

c) gaseous emissions including products of flaring;

d) local dispersion of spilled oil or chemicals;

e) noise, vibration and light including effects of acoustic sources on sea mammals, displacement of marine life from migration routes;

f) ice accumulation and/or pile-up at the facility;

g) physical, chemical and biological impacts at nearby coastal sites.

7.3.7 Far-field sampling

Far-field sampling shall be considered to include locations away from the immediate influence of an offshore facility and should initially be representative of background conditions of contamination and undisturbed biological populations, including onshore coastal areas adjacent to the offshore operations.

Far-field transport and dispersion of discharges of solid and aqueous wastes should be predicted by modelling studies that take into account the physical, chemical and microbiological processes that act on constituents. For offshore Arctic, the following should be considered on a far-field scale:

a) long-term transport of drill cuttings (including solids and chemical constituents) in cold water and ice-prone environments;

b) advection and diffusion of produced water (including chemical constituents, radiation and hydrocarbon contaminants) in oceanic currents, particularly in ice fields;

c) dispersion of spilled oil under different ice conditions;

d) noise generated during operations;

e) products emitted during gaseous discharges dispersed on to ice and snow by air currents.

Techniques for sampling of the seasonal or annually variable ice edge or sea ice, which can enter the near field periodically, shall be developed to meet the specific monitoring objectives for offshore facilities.

7.3.8 Regional sampling

The sampling strategy for an oil and gas field should be harmonized with sampling of the regional sea area, where available, following consultation with the regional authority.

Regional monitoring in seas that include oil basins should be capable of detecting:

a) large scale hydrographical trends, including water and sediment;

b) changes in regional background concentrations of contaminants, including hydrocarbons;

c) variations in biological populations, including commercial species and protected areas;

d) presence of invasive or introduced species;

e) frequency of ship strikes on mammals;

f) coastal and onshore physical, chemical and biological impacts.

Data can be required by authorities as part of state or regional contribution to global monitoring.

7.3.9 Field specific stations

The location of field specific sampling stations should take into account the seasonal or longer term presence of ice in its various forms.

The operator shall document the reasons for the selected field station positioning, based on technical data such as water current pattern and velocities, depth intervals as well as the likely presence of ice at the location. The presence of past operations, such as exploration wells, should be documented.

Any changes to station locations required due to the presence of ice or other factors should be specified in reports. The station history should be documented.

7.3.10 Marine toxicity testing

Marine toxicity tests may be used in conjunction with field sampling to provide information about the possible toxicity of a test material to different life stages of selected species. Tests may include mortality or sub-lethal biological effects.

Results of toxicity tests may be used to predict effects likely to occur in field situations or to set limits on discharges.

Toxicity tests shall use appropriate Arctic species and shall adapt standard guidance for marine toxicity testing to meet the requirements of the selected species and Arctic field conditions. Where non-Arctic species are used for Arctic situations, appropriate provisos shall be documented.

Reference shall be made to existing Arctic toxicity tests results.

Toxicity tests for Arctic species shall be treated statistically in accordance with ISO/TS 20281.

Methods shall be documented and reported.

7.4 Environmental monitoring programme implementation

7.4.1 Pre-development

Prior to development in the Arctic, the operator shall carry out appropriate background studies on the location, including the availability of existing baseline and monitoring data.

