

(Source: OSPAR 12/22/1, Annex 19)

## OSPAR Guidelines in support of Recommendation 2012/5 for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations

(OSPAR Agreement: 2012-7, updated by OIC 2014<sup>1</sup> and OIC 2021)<sup>2</sup>

### 1. Scope of the guidelines

1. These OSPAR Guidelines relate to the provisions and requirements set out in §3 of OSPAR 2012/5 Recommendation for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations. These Guidelines provide general guidance for Contracting Parties, when undertaking periodic environmental risk assessment for all produced water (PW) discharges offshore. They provide a description of each of the stages of the Risk-based Approach, as included in Appendix 1 to the *Recommendation 2012/5 for a Risk -based Approach to the Management of Produced Water Discharges from Offshore Installations*. For discharges in or in the vicinity of vulnerable areas, Contracting Parties (CPs) may decide to deviate from the approach described in the Guidelines.

2. The basis for risk assessment is a PEC:PNEC and/or msPAF approach, which is valid only for substances causing effects by direct exposure through the water phase. Substances that are both bioaccumulative and persistent might cause postponed effects after accumulation of a certain body burden (due to uptake of food), sometimes at great distance from a discharge point. The potential long-term effects of such substances will not be determined within the scope of the Risk-based Approach (RBA) but need to be assessed separately. For substances in offshore chemicals, bioaccumulation and persistence is covered by the harmonised mandatory control system (HMCS) for use and reduction of discharges of offshore chemicals.

### 2. Overview of the Risk Based Approach

3. The RBA towards PW Management is developed following a harmonised, structured procedure presented below (in Figure 1). This framework follows principles of environmental risk assessment already in use in, e.g. the European Union (ECHA - Technical Guidance documents) and United States (US-EPA

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<sup>1</sup> OIC 2014 agreed to replace Table 1 (PNECs and EQSs for naturally occurring substances found in produced water) in Appendix 5 of the OSPAR RBA Guidelines (Agreement 2012/7) with a link to the Background document on the Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water. That Background Document has been uploaded as Agreement 2014-05.

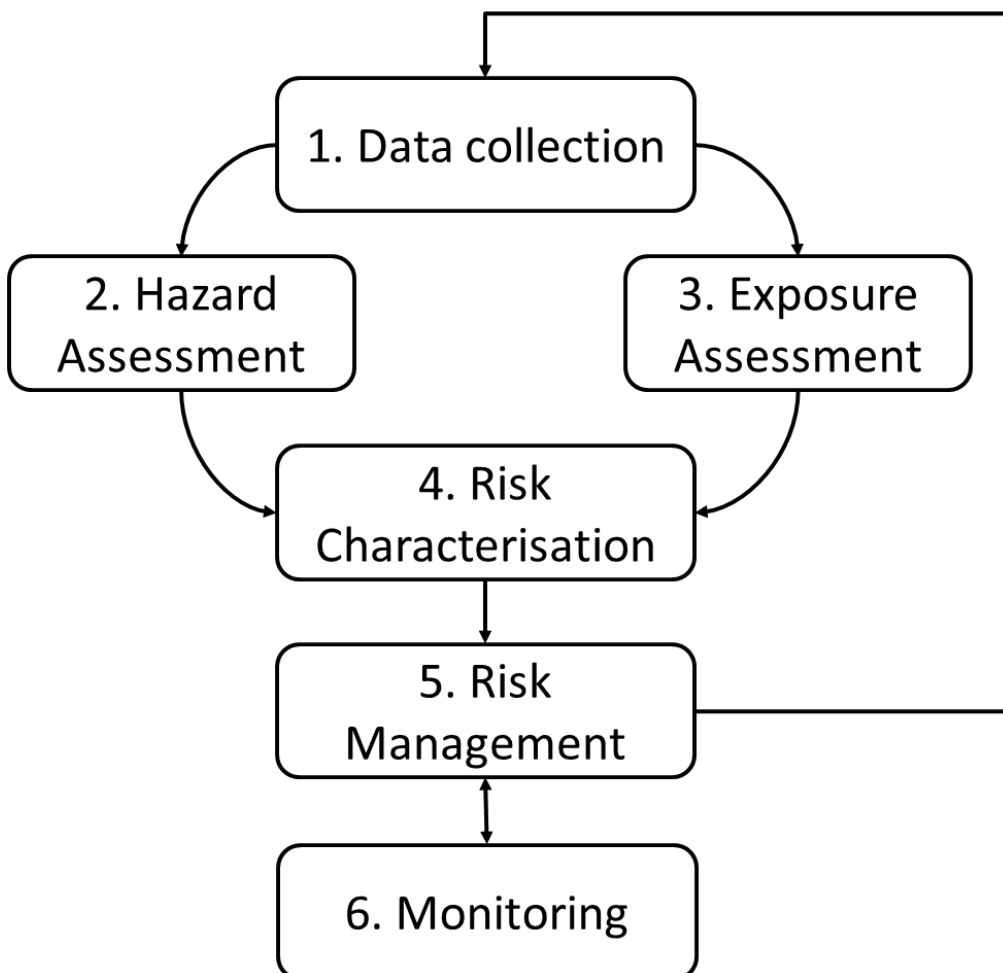
<sup>2</sup> OIC 2021 amended the RBA Guidelines to align with amendments to OSPAR Recommendation 2012/5 for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations by OSPAR Recommendation 2020/3.

Guidance on risk assessment). ECHA has published a series of guidance documents for environmental risk assessment of single substances; the RBA approach has as far as possible been aligned with these guidelines. The assessment of mixtures was developed according to the best scientific practice.

4. To allow for a consistent approach these OSPAR Guidelines refer to published documents, of which the ECHA Guidance on implementation of REACH (May 2008) is one of the key (series of) documents. This minimises the need for updating the Guidelines following a change in external documents.

5. The first step in the RBA process is data collation, in which information on the discharge is collected. The risk is determined using combined information from Hazard Assessment and Exposure Assessment. Contracting Parties should review management options, evaluate measures and develop and implement site-specific actions to reduce those risks which are not adequately controlled. This can involve further data collection and input into the risk-based approach as shown in Figure 1. Monitoring is used in order to verify the effectiveness of any risk management measures.

**Figure 1**



## 2.1 Data Collection – Step 1

6. Data collection involves the collation of relevant information for the level of assessment to be carried out, on the hazardous properties of individual substances and/or the PW effluent, information on discharge

characteristics and information on the local conditions in the receiving environment. This may include information from a combination of sources such as, but not limited to:

- bioassays of PW effluents e.g. whole effluent toxicity (WET), whole effluent assessment (WEA);
- naturally occurring substances: chemical analysis and substance based ecotoxicological information;
- added chemicals discharged with PW: including ecotoxicological information and other information;
- substance physical and chemical properties;
- PW discharge information (volume, depth, temperature etc.); and
- site/field-specific conditions e.g. hydrographic, oceanographic and meteorological data and vulnerability of the area where the discharges are taking place.

### **Bioassays of produced water effluents**

7. The Whole Effluent Toxicity (WET) approach can be used to assess the toxicity of PW. This approach assesses the combined toxicity from all substances in the PW, including unknown substances. WET can be undertaken in its own right or at a more detailed level of assessment in conjunction with the substance-based approach. WET also determines the possible residual toxicity of substances already addressed by current BAT/BEP OSPAR measures, like dispersed oil (OSPAR Recommendation 2001/1 for the management of PW from offshore installations, as amended) and offshore chemicals (OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals, as amended).

8. When carrying out WET testing, it is recommended to follow the A practical program for Whole Effluent Assessment for discharges from the offshore industry (Roex, 2012) or similar guidance. At least a minimum of three *in vivo* bioassays in line with standardized protocols (ECHA Guidance on information requirements and chemical safety assessment, R10.3.2) should be performed, representing three different trophic levels e.g. bacteria, algae and crustacean. It is essential that PW samples for bioassays and for chemical analysis are collected in parallel.

9. Immediate measurements of selected physical-chemical parameters (pH, ammonium, salinity, etc.), is recommended upon arrival of the bioassay samples in the laboratory. This is to allow for adjustment of the samples if considered necessary for performance of the bioassays.

10. As an extension to WET full WEA can be considered which would consist of a combination of tests for determining the potential for bioaccumulation (B), persistence (P) and toxicity (T). Tests are available for detecting adverse effects of substances with specific toxic mode of action. Practical guidance on tests and parameters regarding P and B are described in OSPAR Commission (2007) Practical Guidance Document on Whole Effluent Assessment.

### **Naturally occurring substances (NOS): chemical analysis and substance based ecotoxicological information**

11. Samples of produced water should be collected for chemical analysis of naturally occurring substances (NOS). The PW should be analysed on a minimum set consisting of at least the following groups of substances: heavy metals, BTEX, dispersed oil, 16 EPA PAHs, other PAHs and alkylphenols. Appendix 4 provides an example of NOS for chemical analysis and analyses methods.

12. Examples of procedures for the sampling and analysis of NOS in PW are provided in the following documents (note: Available chemical analysis protocols for PW in general do not include analysis of substances in offshore chemicals):

- OSPAR Agreement 2006-06. Oil in PW analysis. Guideline on criteria for alternative method acceptance and general guidelines on sample taking and handling;
- the 'Produced Water Sampling and Analysis Guidance Notes' from the Department for Business, Energy and Industrial Strategy (BEIS, 2018) in the United Kingdom.

13. Ecotoxicological information on NOS is an important source of data for input to the RBA process. This information is used to estimate PNECs and is described in the "Hazard assessment" step. OSPAR has established a harmonised set of PNEC values for the most common NOS in the PW (see OSPAR Agreement 2014-05 and summary in Appendix 5).

#### **Offshore chemicals discharged with PW: including ecotoxicological information and other information**

14. Information on offshore chemicals discharged with PW is contained in Contracting Party databases generated through the application of the HMCS.

15. The minimum ecotoxicological information for offshore chemicals includes short-term (acute) toxicity data for three trophic levels and is derived from the HOCNF. If data on the individual substances are not available, one could then use the worst case toxicity values for the offshore chemical. Acute and/or chronic data not available in the HOCNF can be obtained to improve the understanding of the toxicity.

16. PLONOR chemicals do not have ecotoxicological data included in the HOCNF but data can be obtained from other sources.

17. Since chemical analysis normally does not include analysis of offshore chemicals, an estimate of concentrations of offshore chemicals (preferably on substance level) must be determined and can be based on daily/monthly/yearly use. Substances posing little or no risk (PLONOR) should not be included unless discharged in large amounts. The most common practical method for the estimation of the quantity of added chemicals (except for surfactants) in PW discharges is based on the water cut and the octanol/water partition coefficients (log Pow) available on substance level from the HOCNF for all non-PLONOR chemicals. For surfactants default values for the fraction released are provided in Thatcher et al. 2005. Other data can be obtained to improve the understanding of the fraction released.

#### **Substance physical chemical properties**

18. Physical-chemical properties may need to be collected for individual substances, such as state (liquid, solid, etc.), molecular weight, density, boiling point, solubility, melting point, vapour pressure and degradation rates. A list of useful sources of physicochemical data is provided in ECHA Chapter R.7a: Endpoint specific guidance (Table R.7.1-2.). Relevant data is provided in the database of EU registered substances<sup>3</sup>.

#### **Produced water discharge information**

19. The model selected for estimation of the dilution potential (described in step 3) will determine which discharge characteristic information and physicochemical information is necessary. The following information may typically be required to enable assessment of the dispersion of the PW plume in the surrounding water:

- geographical position of discharge location;
- discharge volume/discharge rate;
- discharge depth;
- discharge arrangement (e.g. diameter and orientation of discharge pipe);
- salinity;

<sup>3</sup> <http://apps.echa.europa.eu/registered/registered-sub.aspx>

- temperature; and
- information regarding other discharges at the location (e.g. cooling water, ballast water discharge from the platform or discharges from neighbouring platforms).

#### **Site/field specific conditions**

20. In the exposure assessment (step 3) the predicted fate of PW in the receiving environment is determined. For the purpose of modelling the dilution/dispersion in the receiving environment, information regarding the environmental parameters at the location/area is useful.

This could include:

- local/ ocean current data;
- hydrographical data;
- wind data;
- air temperature;
- water depth; and
- information on vulnerable areas (e.g. OSPAR Marine Protected Areas; OSPAR List of Threatened and or Declining Species and Habitats; Special Protection Areas (SPA's), and Special Areas of Conservation (SACs).

## **2.2 Hazard Assessment – Step 2**

21. Hazard Assessment is the first evaluation step in the process, in which the hazard (i.e., the inherent capacity to cause adverse effects) of the discharge is evaluated, either on the basis of properties of the effluent or of the individual substances (both added and naturally occurring).

#### **PNEC based on substance data**

22. The hazard assessment requires derivation of PNECs derived from single species laboratory toxicity tests (preferably NOEC). Using already established PNEC values and following ECHA R10 (Characterisation of dose-response for the environment) where necessary, OSPAR has established a harmonised set of PNEC values for the most common NOS in the PW (Agreement 2014-05). If other relevant substances are identified, dedicated PNEC values should be derived. Review and update of the list of PNECs for NOS should be regularly conducted.

23. For offshore chemicals PNEC values should be derived from data provided in the HOCNF following ECHA R10 (tables R10-4 and R 10-5), with a maximum assessment factor of 1000 as explained in Appendix 6. Similar approach should be followed for PLONOR chemicals discharged in large amounts.

#### **PNEC based on WET data**

24. A PNEC for the whole PW effluent can be calculated on the basis of the WET data that was collected as part of the Data Collection stage. Although developed for single substances, for derivation of the PNEC, guidance from ECHA R10 should be applied with a maximum assessment factor of 1000 as explained in Appendix 6.

## **2.3 Exposure Assessment – Step 3**

25. Exposure assessment is carried out to determine the fate of discharged PW. Again, a difference is made between an assessment based on the effluent as a whole and an assessment based on the combination of individual substances.

## **Principles of Exposure assessment**

26. The purpose of the exposure estimation or assessment is to derive the PECs for the receiving environment around an offshore installation. The PEC can be determined by modelling the concentrations in the receiving environment. As a minimum, the PEC should be determined within the column of water the radius of which is defined by the distance from the installation (e.g. 500m zone) specified by the CP, or within the volume of water directly impacted by the discharge (as determined by hydrographic modelling of dispersion of the discharge), that is specified by the CP, taking into account local environmental conditions.

27. The PEC may be predicted by use of a 1-, 2- or 3-dimensional dilution/dispersion model. It should be demonstrated that dilution is not overestimated by the model by use of (peer reviewed) field validation study(s). Furthermore, the model chosen should be well documented and its users should be well trained. If available, a model that takes account of different fate processes should be used (see also paragraphs 19 and 20). This will provide a more accurate PEC.

### **Exposure assessment following a substance based approach**

28. The output from the substance based exposure assessment is the concentration of substances discharged with the PW in the receiving environment (PEC).

### **Exposure assessment following a WET based approach**

29. The output from the WET based exposure assessment is the concentration of PW effluent (PEC) in the receiving environment, expressed as a percentage of the original effluent.

## **2.4 Risk Characterisation – Step 4**

### **General principles of Risk characterization**

30. Risk characterisation is the comparison of the predicted environmental concentration of the substance and/or the effluent (PEC) and the hazard (PNEC) at a given distance as a minimum.

31. The risk can be further characterised by identification of the contribution of the individual substances (both NOS and substances in offshore chemicals) or groups of substances to the overall risk.

### **Risk characterisation following a WET based approach**

32. The PNEC value calculated in the Hazard Assessment and the PEC value calculated in the Exposure Assessment are used to determine the PEC:PNEC ratio for the whole effluent.

### **Risk characterisation following a substance based approach**

33. If risk estimates are calculated on a substance based approach, the PEC:PNEC ratios for the individual identified substances should be combined to calculate the overall risk estimate for the PW. ECHA does not provide guidance for mixtures; therefore a combined approach based on species sensitivity distributions should be followed (msPAF, De Zwart and Posthuma, 2005). Appendix 7 provides further guidance on how a combined approach may be carried out.

### **Using information from the combined WET- and Substance based approach**

34. Results from both the WET and substance based approach are considered different lines of evidence, both containing complementary pieces of information. Both sets of data can be used to inform the risk assessment (see Appendix 8 for more information).

## 2.5 Risk Management – Step 5

### Risk reduction

35. If the exposure level does not exceed the PNEC outside a column of water surrounding the installation, the radius of which is defined by a distance from the installation specified by the CP, or outside the volume of water directly impacted by the discharge (as determined by hydrographic modelling of dispersion of the discharge) that is specified by the CP, the risk should be considered to be adequately controlled. If this is not the case, CPs should then review management options and the application of BAT and BEP and implement site-specific actions to reduce the risks.

36. For effective risk reduction it is useful to have insight into the most important contributors to the risk. The intermediate results of the substance based risk characterisation may provide insight into those substances contributing most to the overall risk. Also, Toxicity Identification and Evaluation (TIE) or equivalent methods may provide insight into those substances contributing most to the overall risk of the effluent (Sauer et al., 1997, Balaam et al., 2009, Thomas et al., 2009). The results may assist in identifying BAT and BEP.

### Refinement of the risk characterisation

37. The risk characterisation can be dominated by uncertainty leading to high assessment factors in the derivation of the PNEC. Therefore, before looking at physical measures it may be prudent to address uncertainty as reductions here can reduce the resultant PEC:PNEC ratio by factors of 10-100 (reducing uncertainty resulting in lower assessment factors will generally reduce the risk). This may be achieved by, for instance, the collection of additional data and/or undertaking additional toxicity testing to obtain more reliable PNECs,

38. The calculation of the PEC is also subject to a degree of uncertainty. To obtain more reliable PECs a variety of options could be considered including more advanced dilution/fate modelling, review/additional of chemical analysis, better assessment of fraction released for offshore chemicals, etc

### Measures

39. Risk reduction measures (OSPAR Commission publication on the Background Document concerning Techniques for the Management of Produced Water from Offshore Installations) may comprise some or all of the following:

- technical measures, such as abatement at the source by redesign of the applied processes (water shut off in the well);
- substitution of chemicals;
- application of closed systems (e.g. injection of produced water);
- end-of-pipe techniques such as separation or clarification techniques to treat PW prior to discharge, and;
- organisational measures such as management systems in place (training, instructions, procedures and reporting).

40. The application of BAT and BEP should be demonstrated as described in Appendix 1 of the OSPAR Convention.

41. When setting priorities and in assessing the nature and extent of the measures and their time scales, CPs should use the criteria as mentioned in Appendix 2 of the OSPAR Convention.

42. Further explanation on the evaluation and implementation of Risk Management Measures is provided by ECHA (Chapter R13: Risk management measures and operational conditions).

## Review and update of the environmental risk assessment

43. Each CP should determine how often the environmental risk assessment process should be undertaken. Typically, a review and update take place when there is a significant change in the PW discharge (characteristics) due to implementation of risk reduction measures or other modifications, such as:

- Implementation of new end-of-pipe technique;
- Substitution of offshore chemicals or new chemicals taken into use;
- Significant change in the discharge of offshore chemicals; and
- Tie-in of new PW streams (satellites) and/or new wells.

44. An update of the environmental risk assessment would imply that the process should be restarted at step 1 (data collection) as shown in the flow diagram (Figure 1), and that the risk assessment process should be repeated with new and updated information.

## 2.6 Monitoring - Step 6

45. Monitoring is a key element in the verification of the effectiveness of measures adopted for the reduction of the risk. Monitoring refers to the monitoring of PW effluents (effluent monitoring) and the monitoring of the receiving environment (field monitoring). Monitoring is an on-going, iterative process, that is performed on a periodical basis, or when significant changes have been made to the installation that might affect the discharge. The outcome of the monitoring process is used as additional information in the risk management process.

### Effluent Monitoring

46. Effluent monitoring may include the gathering of information from chemical analysis and / or WET/WEA tests on PW samples taken periodically.

### Field monitoring

47. Field monitoring may be used to validate the risk characterized in the RBA process. It may include chemical analysis of seawater and chemical and biological analysis of biota samples (biological effect monitoring) collected from the vicinity of offshore installations. Relevant international standards, and OSPAR Agreement 2017-02 on "Guidelines for Monitoring the Environmental Impact of Offshore Oil and Gas Activities" should be taken into account before field monitoring of the water column is carried out.

48. The monitoring program needs to be designed to be fit for the purpose and to take account of specific field conditions, future field activities and discharges and existing knowledge of previous monitoring in similar or nearby area (OSPAR Agreement 2017-02).

## 3. Documenting the risk assessment and management

49. With the objective of documenting the risk assessment process the following information may be reported in order to provide an audit trail of the assessment:

- PW sampling and analysis monitoring programmes, techniques and results;
- whole effluent based risk assessment methodologies and results e.g. WEA, WET;
- substance based risk assessment methodologies and modelling results; together with any derived PNEC values which are not listed in Appendix 5
- substances identified in PW likely to pose a risk to the marine environment;
- the criteria used to assess whether risk is adequately controlled (e.g., distance and/or volume); and
- field monitoring techniques.



## List of Abbreviations

Abbreviation	Full text	Explanation / definition/reference
BAT	Best Available Techniques	OSPAR Convention, Appendix 1
BEIS	Department for Business, Energy, and Industrial Strategy	<a href="https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy">https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy</a>
BEP	Best Environmental Practice	OSPAR Convention, Appendix. 1
BTEX	Benzene, Toluene, Ethyl Benzene and Xylene	Collection of the aforementioned substances
CP	Contracting Parties	Countries being a part of OSPAR
EC	European Commission	<a href="http://ec.europa.eu/index_en.htm">http://ec.europa.eu/index_en.htm</a>
EC50	Median effect concentration	Explained under Glossary, Appendix 2
ECHA	European Chemicals Agency	<a href="http://echa.europa.eu/">http://echa.europa.eu/</a>
EPA	United States Environmental Protection Agency	<a href="http://www.epa.gov/">http://www.epa.gov/</a>
EPA PAH	List of 16 PAHs with high priority assigned by the EPA	
GC/FID	Gas Chromatography with Flame Ionization Detection	Analytical device for separation and detection of chemicals
GC/MS	Gas Chromatography with Mass Spectrometry	Analytical device for separation and detection of chemicals
HC5	5% Hazardous concentration	Explained under Glossary, Appendix 2
HMCS	Harmonised Mandatory Control System	OSPAR Decision 2000/2
HOCNF	Harmonised Offshore Chemical Notification Format	OSPAR Guidelines 2010-5
LC50	Median lethal concentration	Explained under Glossary, Appendix 2
msPAF	Multi-substance Potentially Affected Fraction	Explained under Glossary, Appendix 2
NOEC	No Observed Effect Concentration	Explained under Definitions
OIC	Offshore Industry Committee	<a href="https://www.ospar.org/work-areas/oic">https://www.ospar.org/work-areas/oic</a>
OSPAR	OSlo-PARis Convention	<a href="http://www.ospar.org">http://www.ospar.org</a>
PAF	Potentially Affected Fraction	Explained under Glossary, Appendix 2
PAH	Polycyclic Aromatic	A chemical class of substances that are present in produced

	Hydrocarbons	water, some of which are carcinogenic
PBT	Persistence Bioaccumulation Toxicity	Explained under Glossary, Appendix 2
PEC	Predicted Environmental Concentration	Calculated or estimated concentration in the environment used in environmental risk assessment
PLONOR	Pose Little Or NO Risk	OSPAR list of substances / preparations used and discharged offshore which are considered to pose little or no risk to the environment
PNEC	Predicted No Effect Concentration	the concentration of a chemical or effluent below which adverse effects on the aquatic ecosystem and its organisms will most likely not occur during long-term or short term exposure
PW	Produced Water	By-product of oil and gas extraction
RBA	Risk -based Approach	Approach for the management of PW as proposed by the OIC (08/13/1-E)
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances	EC regulation for chemicals (EC 1907/2006)
TIE	Toxicity Identification and Evaluation	Explained under Glossary, Appendix 2
TMA	Toxic Mode of Action	Explained under Glossary, Appendix 2
US-EPA	See EPA	
WEA	Whole Effluent Assessment	Explained under Glossary, Appendix 2
WET	Whole Effluent Toxicity	Explained under Glossary, Appendix 2

## Glossary

### **HC5:**

The 5% Hazardous Concentration (HC5) is the exposure concentration of a substance at which 5% of biota are exposed above their effect concentration (usually NOECs). In general, the HC5 level is extrapolated from a limited, but representative, set of NOECs by fitting a cumulative statistical distribution (log-normal in these guidelines) to the NOEC data.

### **LC50/EC50:**

The toxicity data are typically reported as the concentrations at which x % (e.g. 50%) mortality or inhibition of a function (e.g. growth) is observed and are expressed as the lethal concentration (LCx) or the effect concentration (ECx), e.g. LC50 or EC50. L/EC50-values are usually obtained from short term tests (duration in the range of hours to a few days, depending on the test organism).

### **msPAF:**

For a more detailed explanation of the single-substance Potentially Affected Fraction, see 'PAF'. The multi-substance PAF (msPAF) is the fraction or percentage of biota that are potentially affected when exposed to a specific mixture of substances.

### **NOEC:**

Results of long term tests exposed to a substance for a prolonged period in relation to the length of the life-cycle of the organism are most frequently reported as L/ECx (x being very often equal to 10) or as the NOEC (No Observed Effect Concentration) which corresponds to the highest tested concentration for which there are no statistical significant effect when compared to the control group. The endpoints most frequently used are growth inhibition and reproduction.

### **PAF:**

The Potentially Affected Fraction (PAF) is the fraction or percentage of biota that is exposed above their effect level (usually the NOEC level) at a specific exposure concentration of a substance. This fraction is extrapolated from a limited, but representative, set of NOECs for the substance, by fitting a cumulative statistical distribution (log-normal in these guidelines) to the NOEC data.

### **PBT:**

Three intrinsic properties of chemicals called Persistence, Bioaccumulation potential and Toxicity (PBT). Persistent substances are substances that are not readily (bio)degradable in the environment. Bioaccumulative substances are substances that have a potency to concentrate in biota along the food-chain. Toxic substances are substances with low effect concentrations (e.g. NOECs).

### **TIE:**

Toxicity Identification and Evaluation (TIE) is a cycle of procedures relying on combinations of physical/chemical manipulations and toxicity tests to characterize, identify, and confirm the causes of measured toxicity in a sample (for instance an effluent).

### **TMA:**

Toxic Mode of Action are classes of (molecular) mechanisms by which chemicals exert their adverse effect. These classes are used in the calculation of the msPAF. For chemicals with a similar mode of action, exposure levels should be summed, while for substances with different modes of actions, effect levels should be summed.

### **WEA:**

Whole Effluent Assessment is the assessment of the whole effluent in terms of all three PBT properties (or even more generic).

### **WET:**

Whole Effluent Toxicity is the toxicity of the whole effluent. For this purpose, the effect level of a biota to a dilution series of the effluent is tested in the laboratory and is expressed, for instance, a NOEC or LC50/EC50.

## List of References

### Key References

- BEIS Department for Business, Energy and Industrial Strategy (2018). Methodology for the sampling and analysis of produced water and other hydrocarbon discharges.
- ECHA Technical Guidance Documents, to be found on the ECHA website:  
<http://guidance.echa.europa.eu>
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- Thomas, K.V., K. Langford, K. Petersen, A.J. Smith, K.E. Tollefsen (2009). Effect-directed identification of naphthenic acids as important in vitro xeno-estrogens and anti-andrgens in North Sea offshore produced water discharges. *Environmentals Science Technology*, vol. 43, pp. 8066-8701.
- US-EPA Guidance on Risk Assessment, to be found on the US-EPA website: [http://www.epa.gov/risk\\_assessment/](http://www.epa.gov/risk_assessment/).

### Example of a Norwegian Chemical analysis program of produced water

Table 1: Overview of produced water substances (naturally occurring) included in the analysis program, recommended analytical methods and normal limits of quantification ranges (LOQ) shown in bold as referred to in 085 - Norwegian Oil and Gas recommended guidelines for sampling and analysis of produced water (2012). Lower LOQs may be used if possible (examples from Equinor installations shown in non-bold). For detailed information see 085 - Norwegian Oil and Gas guideline.

Main group	Substances	Method	Standards	Detection limit (µg/L)
<b>Metals and metalloids*</b>	Arsenic	HG-AAS/ICP-MS /DRC-ICP-MS	EPA 200.7/200.8	0,173 - <b>1</b>
	Cadmium	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,015 - <b>6</b>
	Chromium	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,184 - <b>1,5</b>
	Copper	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,1 - <b>6</b>
	Mercury	CV-AAS/Au amalgamation	EPA 200.7/200.8	0,002 - <b>0,1</b>
	Lead	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,3 - <b>1,5</b>
	Nickel	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,411 - <b>9</b>
	Zinc	AAS/ICP-MS /DRC-ICP-MS /HR-ICP-MS	EPA 200.7/200.8	0,856 - <b>15</b>
	Iron	AAS/ICP-MS/DRC-ICP-MS/ICP-AES	EPA 200.7/200.8	<b>1</b>
	Barium	AAS/ICP-MS/DRC-ICP-MS/ICP-AES	EPA 200.7/200.8	<b>10</b>
<b>Mono Aromatic Hydrocarbons (BTEX)**</b>	Benzene Toluene Ethylbenzene Xylene (p, m, o)	GC-MS or GC-FID Headspace or purge-and-trap	ISO 11423-1	20 – 100 (individual component)

Main group	Substances	Method	Standards	Detection limit (µg/L)
Dispersed oil	C7-C40	GCFID	OSPAR 2005-15***	0,4
Polycyclic Aromatic Hydrocarbons (16 EPA)	Naphthalene, acenaphthylene, acenaphthene, fluorine, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a)anthracene, benzo (ghi)perylene, indeno(123cd)pyrene,	GC-MS		<b>0,1</b> (sum) 0,01 (individual component)
<b>Other PAHs:</b>	Dibenzothiophene1-methylnaphthalene, 2-methylnaphthalene, 9-methylnaphthalene, 4-methyldibenzo-thiophene, 2,6 dimethyl naphthalene, 9-ethyl-phenanthrene, 4-ethyl-dibenzothiophene, trimethylphenanthrene, 2-isopropylnaphtalene, 1,2,6 trimethyl-phenantrene	GC-MS		<b>0,1</b> (sum) 0,01 (individual component)
Alkylphenols	Sum C0-C3, C4-C5 and C6-C9 alkylphenols	GC-MS ****	See Table 2.1 (NOG, 2012)	0,1
Organic acids	Formic acid, acetic acid, propionic acid, butanoic acid, pentanoic acid, naphthenic acid	ITP or GC-MS		2000 (individual component)

\*The LOQ is specified on the basis of background level of metals (total content) in the North Sea.

\*\* BTEX LOQ: 10 µg/L (summarised).

\*\*\*This is a modification of NS-EN ISO 9377-2. Other methods can also be used if these are calibrated with the OSPAR reference method.

\*\*\*\*Methods used should avoid interference from benzoacids.

AAS: Atomic absorption spectroscopy

DRC-ICP-MS: Dynamic reaction cell inductively coupled plasma mass spectrometry

HR-ICP-MS: High resolution inductively coupled plasma mass

CV-AAS: Cold vapour atomic absorption spectroscopy  
HG-AAS: Hydride generation atomic absorption spectroscopy spectrometry  
ICP-MS: Inductively coupled plasma mass spectrometry  
ICP-AES: Inductively coupled plasma atomic emission spectroscopy  
ITP: Isotachophoresis

## References

1. [085 - Norwegian Oil and Gas recommended guidelines for sampling and analysis of produced water \(2012\)](#). Updated version of 2003 guideline.



### Establishment of a list of PNECs for naturally occurring substances (NOS)

Harmonised use of the list of PNECs enables sharing of information and comparison of the risk assessment results among Contracting Parties. This list should be maintained by OSPAR and updated on a regular basis (e.g. every 5-10 years) or as new scientific data become available. The PNEC list does not include added chemicals. Derivation of PNECs for added chemicals is described separately in paragraph 24 and Appendix 6 of the Guidelines.

The selection of PNECs for the list was based on the following prioritisation:

1. Environmental Quality Standards (EQS) derived under the WFD established for Priority Substances
2. Reliable PNECs derived from EU RARs
3. Reliable PNECs or EQS from publicly available literature sources

More detailed information about the PNEC selection can be found in the PNEC background document (Agreement 2014-05).

NB: [Background document on the Establishment of a List of Predicted No Effect Concentrations \(PNECs\) for naturally occurring substances in produced water](#) was adopted as an OSPAR Agreement in 2014.

### Use of marine assessment factors

The practical programme highlighted the fact that the assessment factors set out in ECHA and the 2003 Technical Guidance (TGD) for Deriving Environmental Quality Standards<sup>1,2</sup> have the potential to have a negative impact on the RBA approach by masking the overall contribution to produced water toxicity from natural components. This is a consequence of the introduction of an additional factor of 10 to the assessment factors derived for the marine environment.

The purpose of the RBA recommendation is to provide data to inform sound decisions on measures to reduce the risk from the discharge of produced water. The effect of the additional factor may be implementation of the wrong measures.

In a review of the science behind the additional factor, the Scientific Committee on Health and Environmental Risks<sup>3</sup> (SCHER) commented (Comment 15) that they did not accept the additional safety factor of 10 as a default for marine ecosystems as being generally justified. In the opinion of SCHER, the use of different approaches for both freshwater and marine ecosystems should be scientifically justified on a case-by-case basis.

Given the potential impact on their work, the ICG-RBA group notes that:

- The TGD recognises that there is a harmonised mandatory control system for the use and discharge of offshore chemicals already agreed within OSPAR (OSPAR 2000a; 2000b) and that the methodology proposed by OSPAR can be taken into consideration in determining assessment factors.
- The assessment factors proposed for the development of environmental quality standards are not directly relevant to determining whether there has been adequate dilution of offshore discharges within a specified water volume or area immediately adjacent to an offshore installation, as dispersion outside that zone ensures that acceptable water quality standards are rapidly achieved and maintained.
- The assessment factors within TGD 1993 originally proposed for risk assessment have been used control chemical discharges from offshore installations for a number of years, and monitoring studies have indicated that they provide an appropriate level of protection to the ecosystem function<sup>4</sup>.
- Discharges under OSPAR 2001/1 and 2012/7 are subject to strict control including requirements for hazard/risk assessment before discharge and regular review of BAT.

Given the existing safeguards, the aims of the ICG-RBA and the implementation of BAT and BEP, the ICG-RBA therefore proposes to continue to use the assessment factors set out in the 1996 Technical Guidance Document on Risk Assessment<sup>5</sup>, which includes a maximum safety factor of 1000.

### References

1. ECHA Guidance on information requirements and chemical safety assessment. Chapter R.10: Characterisation of dose [concentration]-response for environment, May (2008). <http://echa.europa.eu/web/guest/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment>.
2. EC. (2006). Technical Guidance Document on Risk Assessment in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances.
3. SCHER (2010). Scientific Committee on Health and Environmental Risks, Opinion on the Chemicals and the Water Framework Directive: Technical Guidance for Deriving Environmental Quality Standards, October 2010.

4. Smit, G.D.M., T.K. Frost, S. Johnsen (2011). Achievements of risk based produced water management on the Norwegian Continental Shelf (2002-2008). *Integrated Environmental Assessment and Management*, Vol 7, No. 4, pp 668-677.
5. EC (1996). Technical Guidance Document in support of the Commission Directive 93/67/EEC on Risk Assessment for New Notified Substances and Commission Regulation (EC) No 1488/94 on Risk Assessment for Existing Substances. Parts 1-4. Office for Official Publications of the EC, Luxembourg

### Example methods for calculating an overall risk estimate for produced water for the substance based approach

*In the Risk Assessment step, for all substances and/or groups of substances a PEC:PNEC ratio is calculated. In order to arrive at single risk indicator that represents the overall risk of the produced water, these individual PEC:PNEC ratios should be combined. There are several methods available for this, ranging from straightforward summation of the PEC:PNEC ratios to more comprehensive methods that are scientifically more correct. This appendix describes two methods for calculating an overall risk estimate from individual PEC:PNEC ratios including their scientific validity. The two methods presented only serve as examples. More methods are available and new methods will be developed when science evolves.*

The simplest way of calculating an indicator for the overall risk of the produced water is by summing all individual PEC:PNEC ratios. This  $\Sigma$ PEC:PNEC, for instance at a certain distance from the discharge source, can serve as an indicator for the overall risk, subject to risk reduction.

#### **Method 1. Summation of PEC:PNEC ratios (concentration addition)**

$$\Sigma \text{PEC:PNEC} = \text{PEC:PNEC}_1 + \text{PEC:PNEC}_2 + \dots + \text{PEC:PNEC}_n$$

Backhaus et al. (2003) provides two mechanisms to calculate chemical mixtures, which are a concentration addition for similar acting substances and for dissimilar acting substances an independent action as a main mechanism. This defends the selection of a simple method like summing up PEC:PNEC ratios to establish a risk indicator for the produced water. However, if the mixture contains dissimilar acting chemicals, independent action is probably scientifically the better choice, since the relation between the risk (i.e. the likelihood of adverse effects to occur) and the PEC:PNEC ratio might not be equal for all substances and/or substances groups.

Species Sensitivity Distributions (SSDs) describe the relationship between the PEC and risk. For these distributions the risk (likelihood of adverse effects to occur) is expressed as the potentially affected fraction (PAF) of species, or, in other words, the likelihood of a randomly selected species to be affected above a defined effect level (e.g. NOEC or EC50 level, depending on what toxicity metric is used to establish this distribution).

When based on chronic NOECs, the 5% risk level (PAF) from an SSD corresponds to an exposure level that is equal to the PNEC (in line with the HC5 definition for PNEC, Van Straalen en Denneman, 1989). A SSD based on chronic NOECs can therefore easily be transformed into a PEC:PNEC to risk curve by dividing the measure of exposure on the x-axis by the PNEC. After this transformation the x-axis becomes unit free and the value of 1 on the x-axis (PEC:PNEC ratio) then corresponds with the 5% PAF (See figure A for an example). PEC:PNEC to risk curves can be developed for different Toxic Modes of Action and are equal for all substances and/or substance groups with the same Toxic Mode of Action.

The only parameter needed to establish a PEC:PNEC to risk curve for a specific Toxic Mode of Action is a measure of interspecies variation (the slope of the SSD describing how the risk changes on increasing exposure). When PEC:PNEC to risk curves have been established for the different Toxic Modes of Action, PEC:PNEC ratios can be calculated into PAF. Finally, the different PAF values can be combined in the overall risk indicator msPAF.

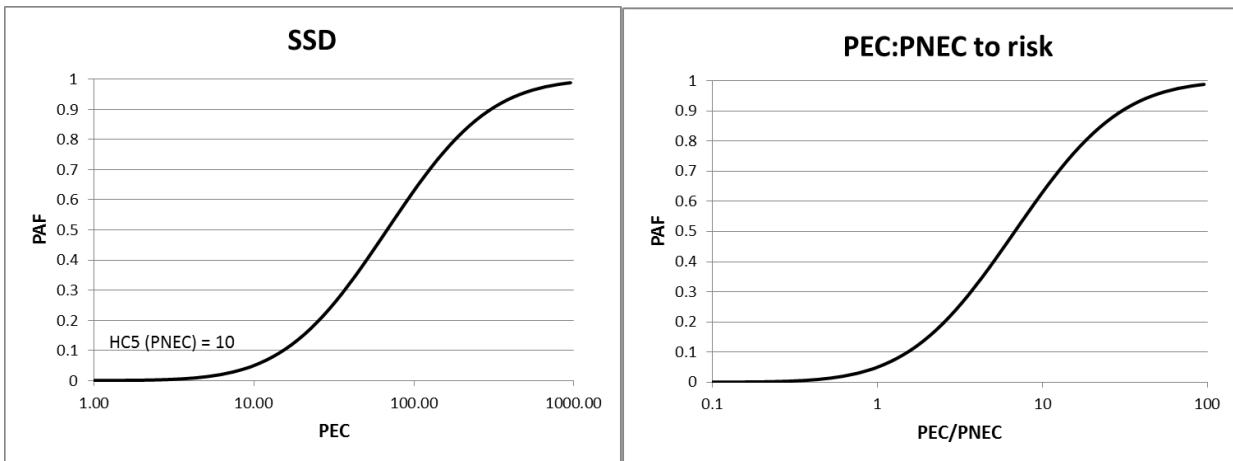


Figure A. Transformation of an SSD to a PEC:PNEC to risk curve by dividing the x-axis of the SSD (PEC) by the value of the PNEC (10 in this example).

### **Method 2.**

#### **Calculation of the multi-substance Potential Affected Fraction (msPAF) of species - independent action.**

1. Sum PEC:PNEC ratios for substances and/or groups of substances with the same Toxic Mode of Action

$$\Sigma \text{PEC:PNEC}_{\text{TMA1}} = \text{PEC:PNEC}_1 + \text{PEC:PNEC}_2 + \dots + \text{PEC:PNEC}_n$$

$$\Sigma \text{PEC:PNEC}_{\text{TMA2}} = \text{PEC:PNEC}_1 + \text{PEC:PNEC}_2 + \dots + \text{PEC:PNEC}_n$$

Etc. for all Toxic Modes of Action

2. Derive a PEC:PNEC to risk curve for each Toxic Mode of Action

A PEC:PNEC to risk curve can be described by a lognormal distribution (often with 10 as base) using two parameters.

X<sub>m</sub>: the mean of the distribution

SD: the standard deviation

The SD of the PEC:PNEC to risk curve is equal to the slope of the Species Sensitivity Distribution. Harbers et al. (2006) published generic SSD slope values for several Toxic Modes of Action.

If LOG10 is used as a base the X<sub>m</sub> of the PEC:PNEC to risk curve can be derived with:

$$X_m = \text{LOG}(1) + (1.6449 \times \text{SD})$$

3. Calculate PAF for each  $\Sigma \text{PEC:PNEC}_{\text{TMA}}$  by using the PEC:PNEC to risk curves
4. The overall risk value (msPAF) is calculated by combining the PAF related to each TMA, using the formula:  $\text{msPAF}_{\text{TMA1+2}} = \text{PAF}_{\text{TMA1}} + \text{PAF}_{\text{TMA2}} - \text{PAF}_{\text{TMA1}} \times \text{PAF}_{\text{TMA2}}$ .

Background information for the method described is provided in Smit et al., 2005.

## References

Backhaus T, Altenburger R, Arrhenius Å, Blanck H, Faust M, Finizio A, Gramatica P, Grote M, Junghans M, Meyer W, Pavan M, Porsbring T, Scholze M, Todeschini R, Vighi M, Walter H, Grimmea LH (2003). The BEAM-project: Prediction and assessment of mixture toxicities in the aquatic environment. *Cont Shelf Res* 23:1757-1796.

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Smit M.G.D., K.I.E. Holthaus, J.E. Tamis, C.C. Karman (2005). From PEC\_PNEC ratio to quantitative risk level using Species Sensitivity Distributions; methodology applied in the Environmental Impact Factor. TNO report B&O-DH - R2005/181, TNO, Den Helder, The Netherlands.

Van Straalen NM, Denneman C.A.J (1989). Ecotoxicological evaluation of soil quality criteria. *Ecotoxicol Environ Saf* 18:241-251.

## Limitations and Advantages of Whole Effluent Toxicity and Substance Based Approaches

	Whole Effluent Toxicity Approach	Substance Based Approach
ADVANTAGES	<ul style="list-style-type: none"> <li>Assesses risk by direct PW testing, i.e. provides direct information on potential toxic effect</li> <li>The effluent is evaluated as a whole, incorporating risks from any unknown toxic components and accounts for synergistic/ antagonistic effects</li> </ul>	<ul style="list-style-type: none"> <li>Can be used to estimate risks at design/EIA stage</li> <li>Enables identification and ranking of substances of concern and these results can be used to target substances or practices for substitution ± amendment</li> <li>Substances' attenuation processes can be modelled (e.g. biodegradation, evaporation, partitioning)</li> </ul>
LIMITATIONS	<ul style="list-style-type: none"> <li>Logistically challenging (sampling, transport, holding times, testing timelines)</li> <li>Difficult to isolate individual substance contributions to toxicity</li> <li>May not account for fate processes: biodegradation, evaporation and partitioning.</li> <li>Physical properties of PW can interfere with toxicity tests e.g. dissolved oxygen and salinity concentrations.</li> </ul>	<ul style="list-style-type: none"> <li>Performed for a limited set of substances. Not 'all' substances can be analysed, and toxicity data is not available for every substance that can be analysed.</li> <li>Requires an assessment of discharge concentrations for substances that cannot be analysed (e.g. offshore chemicals) leading to increased uncertainty</li> <li>Require assumptions to be made for mixture toxicology</li> <li>Requires specific analytical capabilities of local laboratory facilities (e.g. in relation to detection limits)</li> </ul>