

084 – Recommended Guideline for standard EIF calculations for Produced Water Discharges

Offshore Norge

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FORORD

Denne retningslinjen er anbefalt av Offshore Norges fagnettverk for utslippsrapportering og av Offshore Norges Forum klima og miljø. Engelsk tittel vil være Recommended Guideline for standard EIF for Produced Water Discharges. Den er godkjent av administrerende direktør i Offshore Norge.

Formålet med EIF retningslinjen er å levere en standardisert og oppdatert metode for modellering og beregning av Environmental Impact Factor, EIF.

Ved årets oppdatering har representanter fra Nettverk Utslipp til sjø og Forum klima og miljø blitt konsultert for å gi kommentarer og innspill til endringer. Arbeidsgruppen har bestått av representanter fra operatørene Equinor, ConocoPhillips, AkerBP, Vår Energi og Shell, samt Sintef og Offshore Norge (tidligere Norsk olje og gass).

En mindre gruppe med representanter fra Equinor, ConocoPhillips og Offshore Norge har bearbeidet teksten i slutfasen til og med oktober, 2022.

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Denne Offshore Norge Retningslinjen er utviklet med bred bransjedeltagelse fra interesserte parter i den norske petroleumsindustrien og eies av den norske petroleumsindustrien representert ved Offshore Norge. Administrasjonen er lagt til Offshore Norge.

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1 Introduction

The present document is an updated version of the Environmental Impact Factor (EIF) computational Guidelines (NOROG/OLF, 2003) for produced water (PW) discharges. As for the original Guidelines, the purpose of the updated version is to provide a standardized method for modelling and determination of the EIF as a basis for environmental risk management and reporting for offshore discharges of PW in the Norwegian sector of the North Sea, the Norwegian Sea and the Barents Sea. OSPAR Recommendation 2012/5 is implemented in Norwegian legislation in Section 60 of the Activities Regulations. The Recommendation includes requirements to perform risk assessments on discharge of PW, and that best available measures shall be selected in order to reduce risk. Risk assessments should be performed with methods based on comparison of predicted environmental concentrations (PEC) and predicted no effect concentrations (PNEC) on substance level and EIF is suggested used for this. This Guideline shall form the basis for all EIF determinations related to required annual reporting from the oil and gas operators in the Norwegian sector to the Norwegian Environment Agency (NEA). The objective is to secure uniform and standardized EIF determination by all operators, thus facilitating comparison of EIF across years and independent of the party performing the calculations.

The EIF was developed as a part of the DREAM project (1997 – 1999) as a risk assessment-based tool for PW environmental risk management. Due to the conservative nature of the EIF, following the European Commission guidelines (ECHA) for environmental risk assessment of chemicals, both with respect to discharge composition, fate and potential effects, the method does not intend to give an accurate description of the environmental impact of a specific discharge plume. The main purpose of the EIF is to:

- Provide a quantitative expression of the potential environmental risk of a specific PW discharge or discharges
- Assess which substances in the discharge contribute to this risk, based on available knowledge of composition and effect of single substances or groups of substances with similar properties
- Serve as a basis for evaluation of potential adverse effects/risk and/or risk reducing mitigation measures
- Document contribution by mitigating measures on risk reduction and risk development over time

The EIF does not directly reflect the exact environmental impact of a PW discharge. To obtain a field-specific risk assessment more detailed information, both on the local environment (e.g., biological resources of interest), time-variable exposure and effect of the discharged substances are required. Caution should be applied if the EIF is used for direct comparison of different discharges at different locations, or to rank these for the purpose of prioritization, especially if EIF values for such discharges/fields are of similar magnitudes. This is due to the relatively short time window for EIF computation (typically 30 days) and the temporal variations in local oceanographic data, PW discharge composition and volume for the different fields. Uncertainties in the EIF results given the uncertainties in the input data/factors for a specified platform are assessed in a study by SINTEF (Nepstad and Nordam, 2015) and lately by DNV GL (2019).

This guideline describes a recommended procedure for standardized EIF calculations of produced water discharges using the DREAM model (Reed and Hetland, 2002) version 14.0.0 (2022). The MEMW/DREAM User's Manual, the standardised PNEC values from OSPAR Agreement 2014-05, and the description of the EIF methodology given by Johnsen et al. (2000); Smit et al. (2011); Rye et al. (2013) serve as a basis for this document.

This guideline document is divided into sections describing procedures for calculating and presenting EIF results:

- Input data – chemical, physical, biological and meteorological parameters needed
- Model parameters and computational considerations – definitions of concepts and terms, standardised set-up of internal governing model parameters

- Overview of steps in calculating EIF
- Model output and EIF calculation methodology
- EIF reporting

2 Model input data

This chapter describes some standard input parameters and methodology to be used for the annual EIF calculations.

Using these standardised data and methods, the EIF should be determined for PW discharges for a specific year and potentially, over several years and for the lifetime of an installation. A standard dataset for currents and wind shall be used for all fields. The standard dataset of current and wind covers the whole Norwegian Continental Shelf (NCS) and is described in Chapter 2.4. The standardised modelling period is 1.5 – 30.5.2020. The calculated EIF shall represent an average based on discharges throughout the year under normal conditions. If PW is reinjected, the actual discharge is averaged over the year. This means the yearly discharge is divided by 365 days to get the discharge per day.

Other water streams however mixed and released with PW, should not be included in standardized EIF calculations. This applies to e.g.:

- Displacement water containing oil residues
- Oil containing discharge water from jet operations
- Cooling-water (uncontaminated)
- Excess treated injection water (not pumped)

Required input-data for setup and EIF calculation for PW are:

- Location of site (degrees, minutes and seconds)
- Depth of release
- Release rates
- Concentrations of all naturally occurring substances (NOS) and added chemicals in the discharge
- Toxicity data, biodegradation and n-octanol-water partition coefficients according to the HOCNF scheme (Harmonised Offshore Chemicals Notification Format) for all added chemicals in the release. The chemicals should preferably be characterized on a component level.
- Met-ocean data

Near field calculations are not applied for PW discharges.

A detailed list of all input data needed for EIF calculations of PW has been included in Appendix A-1.



2.1 Produced water substances

2.1.1 Naturally occurring substances (NOS)

The list of NOS in PW discharges consists of 26 substances plus eight selected metals included in EIF calculations is presented in Appendix A-2.

The PNEC values for NOS recommended by OSPAR Agreement 2014-05 (OSPAR, 2014) shall be applied and are listed in Appendix A-3. The OSPAR PNEC values are to be updated on a regular basis (e.g., every 5-10 years) or as new scientific data and PNECs become available. Furthermore, a suggestion for grouping of substances is provided. Derivation of PNECs for added offshore chemicals is described separately in Chapter 2.1.2.

Time-averaged EIF.

The *time-averaged* EIF, rather than the maximum EIF should be focused on, as an indicator for risk to marine organisms/ecosystems, whereupon EIF equal to 1 represents a surrounding water volume of 100 000 m³ (100 meter x 100 meter x 10 meter) where toxicity thresholds are exceeded for PW substances. Nevertheless, maximum EIF, expressing the maximum risk during the simulation period, should also be presented to visualize the temporal variations in EIF, basically due to variations in the ocean current speed over the simulation period. The EIF tends to decrease when the speed of the ocean current increase.

2.1.2 Added chemicals

Chemicals used and discharged offshore are categorized according to the areas of application (e.g., drilling and well treatment (area A), production (area B), etc.) as defined in NOROG 044 (NOROG, 2022). The chemicals are then further divided according to the function they have (e.g., corrosion inhibitors, flocculants, etc.).

According to the ECHA Guidance document R16, Ch. 16.2.2.6 (ECHA, 2016) the release of substances can either be defined as continuous or intermittent. Intermittent releases are defined as occurring infrequently, i.e., less than once per month and for no more than 24 hours and continuous substance releases are those occurring at least once a month with a duration of more than 24 hours.

All offshore chemicals that are released to sea with the PW on a continuous basis, in accordance with the ECHA definition above, should be included in the standardized PW EIF calculations in accordance with the Activity regulations §60 (see flow chart in Appendix 8). This will include chemicals within application areas B (production), E (gas treatment chemicals) and H (chemicals from other production sites) but may also include area A (well treatment chemicals) that are injected in a production well and partly flowed back with PW, and C (injection chemicals) which are produced back with PW in the case of water injection breakthrough. Chemicals used during field tests (as defined in Activity regulation §66) are limited to a consumption that does not exceed 14 days and are therefore excluded from PW EIF under the definition of continuous/intermittent release in accordance with ECHA 2016.

Some chemicals are assumed to have little or no effect on the marine environment and are listed as PLONOR chemicals, defined by OSPAR, and are not required to have ecotoxicological documentation. However, as recommended by OSPAR Guideline to a Risk-Based Approach (RBA) to management of PW discharges (OSPAR, 2012), PLONOR chemicals discharged in large volumes (e.g., MEG, methanol), should also be included in EIF calculations, since they potentially contribute to the overall risk.

Physical-chemical properties and ecotoxicological data for all chemicals are derived from the Harmonised Offshore Chemical Notification Format (HOCNF), except for PLONOR chemicals, according to OSPAR Guidelines (OSPAR, 2020). Since chemical analysis of the PW discharge normally does not include analysis of added chemicals, discharge concentrations of added chemicals, preferably on substance level, must be estimated. The most common practical method for the estimation of the fraction released of added chemicals in



PW discharges is based on measurements of the partitioning of the substances between water and n-octanol (Pow) and the water cut. Log Pow is available on substance level from the HOCNF for all organic non-PLONOR chemicals on NCS, except for surfactants which have surface-active properties. For surfactants, default values for the fraction released should be provided, e.g., derived by laboratory or field measurements or by reliable estimations. If substance-specific data are not available, the total amount of the chemical product should be used to estimate the discharge concentration. When selecting a representative substance for the chemical, the same substance is chosen to represent both physical/chemical and ecotoxicological properties.

If no documented water and n-octanol distribution data (log Pow) or reliable estimate of fraction released are available for the chemical product or the individual substances of the chemical, a conservative estimate assuming that 100% of the chemical/substances follows the water phase and discharged to sea should be applied.

The PNEC values for individual substances in chemical product can be derived from acute short-term toxicity data available in the HOCNF. According to OSPAR standards (OSPAR, 2020), toxicity testing of offshore chemicals should be performed on marine organisms, including alga (e.g., *Skeletonema costatum*), crustacean (e.g., *Acartia tonsa*), and fish juveniles (e.g., *Scophthalmus maximus*), representing species at different trophic levels living in the water column. For added chemicals, PNEC values could be derived from data provided in the HOCNF following ECHA R10 (ECHA, 2008), with a maximum assessment factor of 1000, as described in the OSPAR RBA Guideline (OSPAR, 2012). The algal growth inhibition test of the base-set is, in principle, a multi-generation test. However, for the purposes of applying the appropriate assessment factors, the EC50 is treated as a short-term toxicity value. The EC10 or NOEC from this test may be used as an additional long-term result when other long-term data are available. In general, an algal EC10 or NOEC should not be used unsupported by long-term EC10 or NOECs of species of other trophic levels. The PNEC is derived from dividing the lowest acute LC50 or EC50 value by an assessment factor of 1000. If additional chronic toxicity data are derived for a chemical substance, the assessment factor can be lowered according to the criteria described in Table 2.1. If data on the individual substances are not available, the worst-case toxicity value for the product is to be used. Further guidance on which ecotoxicological information can be used to perform the effects assessment is given in the different endpoint specific sections in ECHA Guidance document Chapter R.7b (ECHA, 2017).

Table 2.1 The assessment factor scheme with associated notes described in ECHA R10 applied to the freshwater environment (see Table R.10-4; ECHA, 2008) should be used for added chemicals.

Available toxicity data	Assessment factors*
At least one short-term L(E)C50 from each of three trophic levels (algae, crustaceans and fish)	1 000
One long-term EC10 or NOEC from one trophic level (either fish or crustaceans)	100
Two long-term EC10 or NOEC from species representing two trophic levels (fish and/or crustaceans and/or algae)	50
Long-term EC10 or NOEC from species at least three species representing three trophic levels (fish, crustaceans, and algae)	10
Species sensitivity distribution (SSD) method	5-1 (to be fully justified case by case)
Field data or model ecosystems	Reviewed on a case by case basis

*Notes to Table R.10-4, see Table R.10-4; ECHA, 2008.

2.2 Data on physical and chemical properties

Data on physical and chemical properties of NOS in PW are displayed in the “chemical component database” (Chemdb.mdb) that follows the installation of the DREAM model for EIF calculation (see Appendix A-6). For added chemicals, data on each substance should be added to the chemical component database. The physical-chemical properties of added chemical substances are available from the HOCNF of the chemical product.

Note: A new chemdb.mdb file will be installed with new versions of MEMW and will overwrite the one you have. Save your chemical database by re-naming it before new installations of the model.

Figure 2.1 shows the minimum data input (shown in bold) required for new chemicals or substances for standardised EIF calculations. Notice, if a new chemical or substance should be added to the “chemical component database” select System\Component Editor in DREAM menu, then Database\Chemical components.

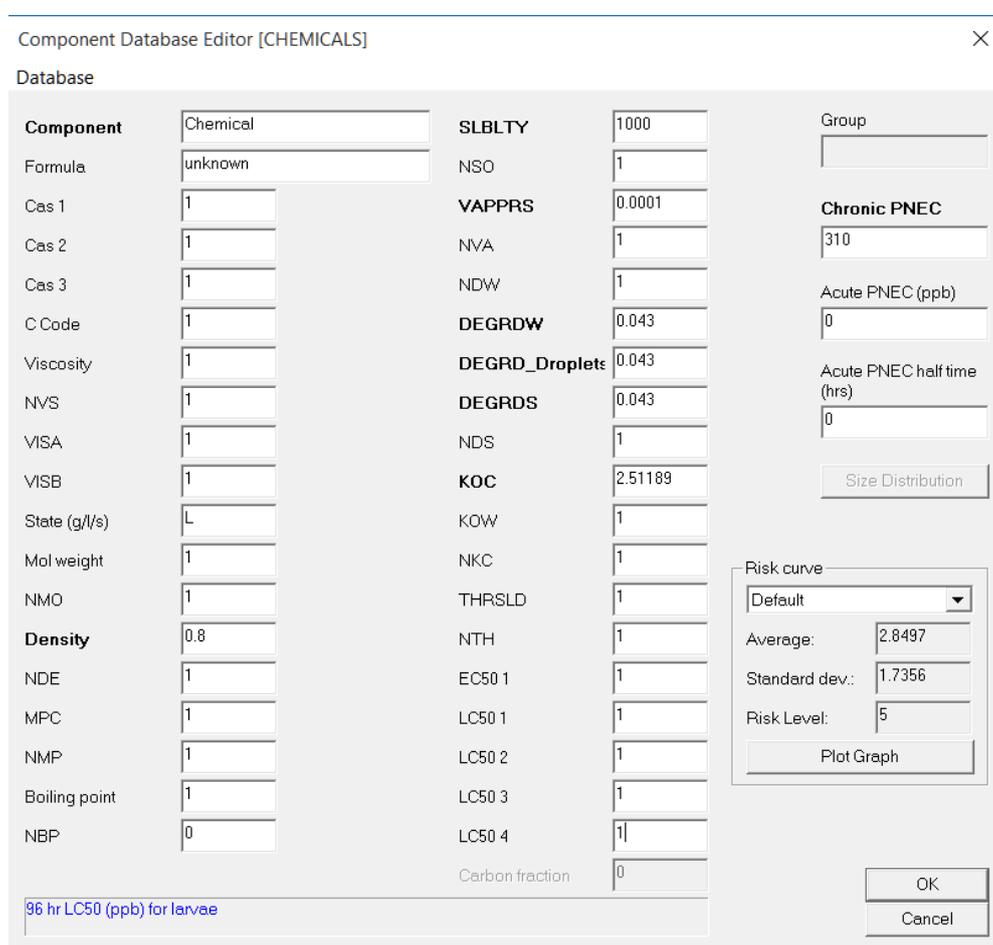


Figure 2.1 Sheet for new chemicals to the DREAM chemical component database. All fields shown in bold in the sheet must be filled with data from HOCNF.

The following procedure should be followed when new chemical substances are entered to the database:

- Naturally occurring substances are included to the database under Database\Load\EIF chemical components.
- To include new added chemicals to the database, select Database\Load\Chemical components. The below mentioned input data needs to be updated for the specific chemical.
- **SLBLTY, solubility:** Chemical substances are assumed highly soluble (solubility > 1000 mg/L).



- **DEGRDW, degradation (water, droplets and sediment): k-value determined** based on the BOD 28-day results derived from the HOCNF for all organic substances (see section below on Biodegradation), assume first order rate, measured at 13 °C. Use the same k-values for both water, droplets and sediment biodegradation.
- **Koc** is not used in PW EIF simulations since we assume all components to be highly soluble. The model requires a number, and as for other use of the model we use the highest Log Pow value from the HOCNF scheme to calculate the Koc. If not available, the default value should be 1.
- **Chronic PNEC** = lowest EC50/LC50 in the HOCNF or chronic NOEC/EC10 derived from long-term toxicity tests divided by an appropriate assessment factor based on toxicity data availability (see Table 2.1). Only the field for “Chronic PNEC” should be filled in for EIF calculations (the acute PNEC fields should remain empty).
- **Density (kg/L)** from HOCNF. If not available, default value is 1.
- **Vapour pressure** is set to 0.001 atmospheres (to minimize evaporative losses) if no data is available.

Other parameters in the “chemical component database” that are not highlighted in Figure 2.1 should be set to unity (value equal 1).

2.3 Biodegradation

See Appendix A-7 showing rate coefficients (k-values) and half-lives for both primary and ultimate biodegradation for NOS. Primary biodegradation is the degradation of the parent substance determined by specific chemical analyses, while ultimate biodegradation represents the complete degradation by non-specific analyses to mineralisation by measurement of biochemical oxygen demand (BOD) or CO₂-evolution. In the EIF calculations ultimate biodegradation of substances should be used as input (Brakstad et al., 2021).

Like, the other physical-chemical data, biodegradation rates are also available on individual substances for added chemicals, as determined by the standard marine BOD test available in the HOCNF. The k-value is determined from the percentage biodegradation within typically 28 days (BOD) using seawater as bacterial source (OECD 306) and should preferably be applied on substance level for each chemical product in the EIF calculations.

For added chemicals representing a mixture of substances, the lowest biodegradation rate measured (BOD 28 test) for the product shall be used if data are not available for some of the single substances.

2.4 Met-Ocean data

The EIF calculation uses a standard dataset of current and wind fields which cover the whole NCS. The current data are produced and offered by the Norwegian Meteorological Institute through the NorShelf model setup, which has a horizontal resolution of 2.4 km, and includes data assimilation (Rörhrs, 2018). Figure 2.2 shows the geographical coverage of NorShelf. Wind data are sourced from the global 30 km horizontal resolution ERA5 dataset provided by ECWMF (Copernicus, 2020). These data are not bundled with the DREAM model and must be downloaded by the user. A guide for obtaining the data files is provided in the Appendix A-9.

The standardised modelling period for EIF calculations is 1.5 – 30.5, year 2020.

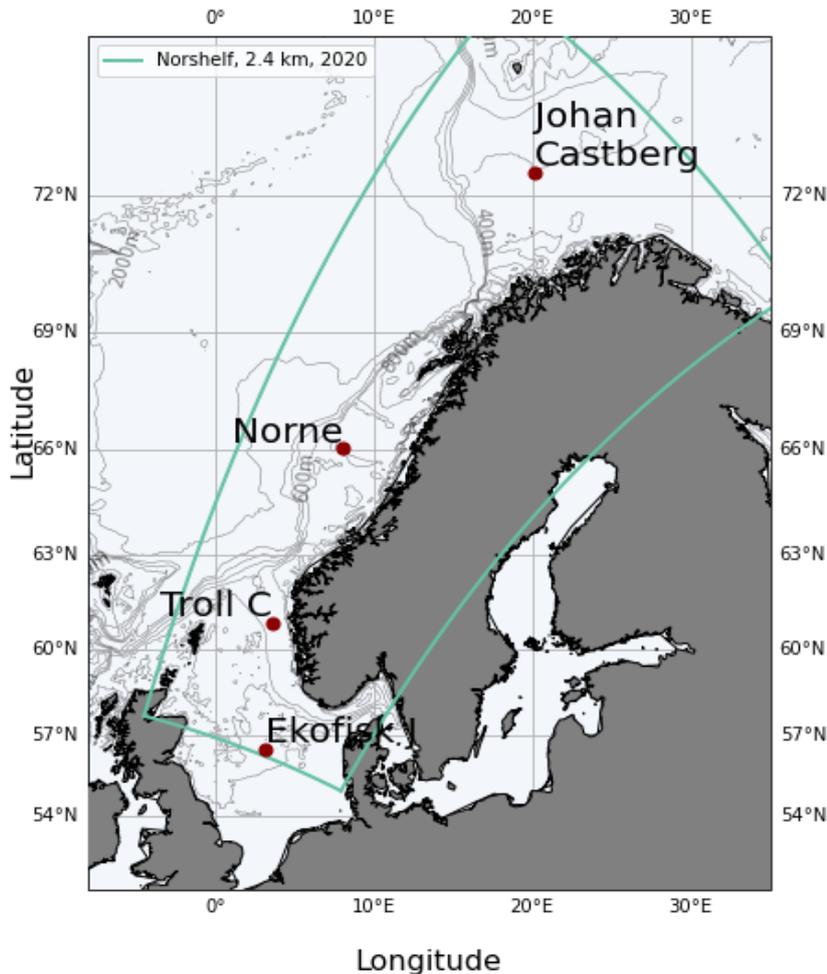


Figure 2.2 Geographic coverage of the NorShelf 2.4 dataset.

3 Model parameters and computational considerations

Chapter 3 addresses the standardisation of internal model input parameters that affect the EIF quantitatively. The proposed values for these variables are all based on comprehensive sensitivity testing of the DREAM model (Reed and Hetland, 2002).

3.1 Definitions

Key concepts discussed in this chapter are defined here:

Grid: a grid is a 2- or 3-dimensional lattice or mesh used to discretize space into individual cells for purposes of numerical computation. For underwater releases in DREAM, all grids are rectilinear, and all cells are of the same size.

Grid resolution: the resolution of a grid refers to the size of individual cells in the grid: smaller cells provide higher **spatial resolution**.

Habitat grid: defines the physical domain in which the model operates. This domain is divided up into rectangular cells, in which land, water, and water depth are defined. The user controls the resolution of the habitat grid when the grid is created. This resolution is generally non-critical to the EIF computation in offshore areas, since there is no need to define coastlines in detail, and because the resolution of the concentration grid is defined independently by the user. On the other hand, the outer extent of the habitat grid defines the maximum geographic area within which water concentrations will be calculated. It is also convenient to use the same resolution of concentration and habitat grid, and this is default in the DREAM model.

Concentration grid: the model computes and reports concentrations in the water column using the concentration grid. This grid is fixed in space and time when an EIF is to be calculated. The resolution of the concentration grid is controlled by the user through specification of horizontal cell resolution and number of vertical layers and maximum depth of the concentration grid, also in the Model Parameters\Physical Fates dialogue, or sidebar.

Lower Concentration Limit: the lowest concentration that will be recorded in the output files. In the Model Parameters dialogue box, set the Lower Concentration Limit to about 10% of the lowest PNEC value in the release. This will ensure that all concentrations with the potential for non-zero risk values will be retained.

Time step: specifies the time interval between subsequent calculations in the simulation. Smaller time steps are required when rates of change are more rapid. A smaller timestep produces increased **time resolution**.

Number of particles: DREAM is a particle-based dilution model. Increasing the number of particles used in a simulation generally increases the statistical stability of the results by increasing the potential **spatial resolution** of the transport process. Experience suggests that 3000 active particles will produce stable results given a 100 m x 100 m concentration grid and a 10-minute timestep.

Output interval: determines at which frequency the concentration fields and risk results are written to the output data files.

EIF: an EIF of unity ($EIF = 1$) is defined as a volume of water with horizontal dimensions of 100 m x 100 m and 10 m ($100\,000\text{ m}^3$) in depth in which the total risk, including contributions from all chemical substances in a release with a PEC/PNEC ratio is higher than 1, or exceeding the multi substance potentially affected



fraction (msPAF) of 5%, which is the fraction or percentage of species that is exposed above their effect level when exposed to a specific mixture of substances (De Zwart and Posthuma, 2005).

3.2 Setting up DREAM for EIF calculation

The establishment of the geographic boundary for an EIF calculation is in general an iterative process. One seeks to balance the need for spatial and temporal resolution against the practical constraint of computational time. The resolution necessary to produce a reasonably accurate EIF for a given release scenario is a function of the:

- Composition of the release,
- Release rate, and
- Current velocities in the area for the duration of the simulation.

The spatial resolution can be increased (i.e., the size of the cells in the concentration grid can be decreased) by

- Decreasing the size of the habitat grid (and thereby the concentration grid), or
- Increasing the number of cells in the concentration grid.

Either method will require a decrease in the timestep in accordance with the new grid size. Increasing the resolution of the concentration grid will increase the running time for the simulation because:

- A smaller timestep, results in more calculations being carried out by the model for a given simulation duration,
- More cells will contain concentration values, increasing the amount of computation to be carried out by the risk tool, and
- More particles will be needed in the simulation to adequately resolve details in the concentration field.

Reducing the size of the habitat grid is desirable in that one can increase the resolution of the concentration grid without increasing the number of cells in the grid. This helps keep computation time down. The limit to decreasing the size of the habitat grid is associated with the need to keep relevant risk areas (i.e., those with $PEC/PNEC > 1$) away from the boundaries, where the loss of particles may artificially reduce the concentration field.

One can establish the final habitat grid in two stages. The first stage, referred to as screening, uses a large grid to establish the approximate extent of the area within which $PEC/PNEC$ exceeds one. The second stage is the actual computation of the risk map upon which the EIF will be based and may itself require a few iterations. A standard procedure for computing an EIF is described below, including potential problems that may be encountered.

3.2.1 Screening

Stage 1: First a relatively large habitat grid is created centred on the release site(s). This grid should retain most (> 90%) of the substance mass released during the simulation. Experience shows that for a large single release (e.g., > 25 000 m³ of PW per day), a habitat grid of approximately 50 km North-South and East-West may be necessary. For smaller releases, a somewhat smaller initial screening area may suffice. The user should check the mass balance at the end of the screening simulation to verify that no more than 10% of the mass is in the “Outside” compartment of the mass balance. A second check should be performed after running the Risk Map tool, to assure that PEC/PNEC higher than one does not appear too near the boundary, as discussed further under Stage 2.

The resolution of the habitat grid is non-critical in most offshore areas but should be fine enough to capture any rapid changes in bathymetry.

Figure 3.1 below shows the menu for creating new grids. One can define the size of an area (grid size) to calculate and the resolution for water-column grid cells (cell size), the number of grid cells is calculated automatically.

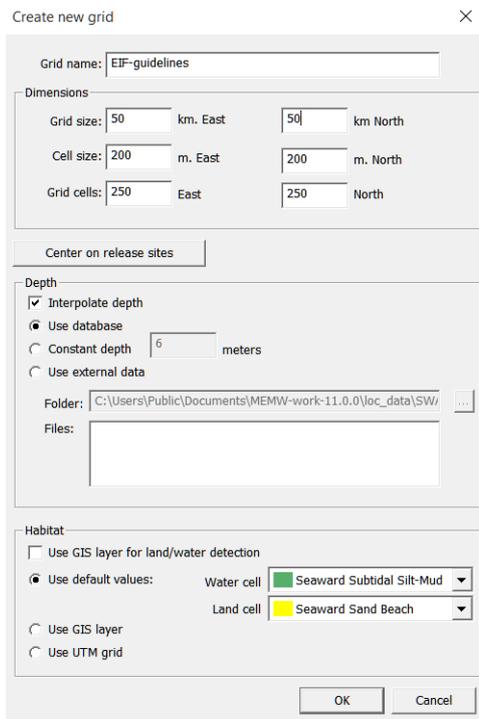


Figure 3.1 Create new grid menu.

The concentration grid for screening can be set to 50 km x 50 km with cell size 200 m x 200 m. This will result in a spatial resolution $50 \text{ km} / 200 \text{ m} = 250$ grid cells in each direction. For relatively small release rates or low chemical concentrations in the release, either a smaller habitat grid or a greater number of horizontal cells in the concentration grid will increase the spatial resolution.

Run the simulation, and the “Create Risk Map” tool.



Table 3.1 Suggested model parameters for screening, assuming a 50 km x 50 km habitat grid.

Model parameter	Value	Comments
Number of Liquid/Solid particles	3 000	Non-critical for EIF computations; given that all components are designated with high solubilities, droplets will have short lifetimes
Number of dissolved particles	3 000	“More is better” here, but less particles gives shorter simulation times
Number of cells in concentration grid (xzy)	250 x 250 x 10	Gives cells resolution at 200 m x 200 m x 10 m in a 50 km grid. The overall size of the concentration grid is the same for the habitat grid. The number of cells can be increased or decreased to change the resolution of the screening run. Individual cells must be small enough to register concentration values exceeding PNEC, at least very near the source.
Lower concentration limit (ppb)	10% of lowest PNEC value in the release	Assures good representation of the concentration field near the outer edges
Depth of concentration grid (m)	Min: 0, Max: 100 m	Results in 10 m vertical layers
Timestep (minutes)	10	Calculation time for the fate calculation for the discharge.
Output interval (hours)	12	Results in 2 samples of model results per day.

3.2.2 EIF computation

Stage 2 proceeds based on the results of the screening simulation. Possible outcomes of the screening scenario are:

1. **The risk field is less than one or zero everywhere;** results from cells being too large to resolve the concentration from the release point(s) in the grid. A finer meshed grid with 50 m resolution should be applied. If 50 m resolution still gives risk less than one or zero, then EIF shall be reported as zero.
2. **The risk field nears or intersects the boundary of the grid,** increase the grid to cover the entire area with PEC/PNEC > 1, plus additional area beyond where the risk intersected the grid boundary.
3. **The risk field is well within the grid.** Decrease the grid to fit the outer boundary of the risk field.

Stage 3 When the grid has been adjusted to cover the risk field, several repetitions are performed to inspect the stability of the simulation. Stability should be within 10% uncertainty.

See examples of screening in Appendix A-4.



Standard resolution for EIF calculations in screening phase:

- For max EIF > 10 use resolution 100 m x 100 m x 10 m for the concentration grid, timestep 10 minutes, output 12 hours, simulation over 30 days
- For EIF < 10 use resolution 50 m x 50 m x 5 m for the concentration grid, timestep 5 minutes, output 6 hours, simulation over 30 days.
- Standard currents and wind data set (see chapter 2.4). The standardised modelling period is 1.5 – 30.5 2020.

3.3 Computational considerations

Dimensions of the concentration grid, the number of particles used to simulate a release scenario, and the computational timestep influence the time to run a simulation and the space required for storage of results.

¹Setting these parameters at standardised values thus represents a compromise between ideally preferred values (i.e., very high resolution in both space and time) and practical possibilities for running large numbers of simulations assuming the use of today's "high-end" personal computers.

Recommended specifications to be used for operational EIF calculations are:

- PC running Windows 7 or newer operating system with administrator privileges
- 64bit Windows 7 or newer
- Minimum recommended configuration: 8 GB RAM,
- 10 GB free space on hard disk

The calculations may be carried out on less powerful machines but will take more time to complete.

¹ The number of components in the release is also a factor that affects processing time but is not considered here since the user has little control in this regard.

4 Reporting

4.1 EIF work sheet

EIF work sheet (*MEMW.xls*) should be reported. Added chemicals should be reported with functional group name (e.g., corrosion inhibitor). Detailed composition of the added chemicals should not be included in the report, use anonymous names with the applied PNEC value for reporting of the results.

However, the operators should save the detailed information related to composition and choice of representative substance for the EIF modelling internally, for potential future applications.

Model parameters: The input data to the *scenario.prv* file from the DREAM model should be reported in an appendix to document the model input parameters.

EIF simulation output:

Contribution to risk from the different NOS and added chemical substances in the discharged water should be reported as a “pie-chart” where the percent contribution to EIF (risk) is shown for the different PW substances.

EIF for the actual reporting year should be reported as the time-averaged value for the standardised modelling period (typically 30 days), discounting the first 10% of the period (the model calculates this automatically).

Standard table and figures for reporting of EIF consist of:

- Table with input data and results for each compound in the discharge.
- Pie chart with the percent contribution to EIF for the various components, along with the calculated maximum and average EIF.
- Time series showing development of the EIF throughout the simulation period.
- Snapshot showing the timestep with maximum risk in the water-column.
- Snapshot showing accumulated maximum EIF for each grid cell through the whole water-column throughout the simulation period (footprints from all time steps).

Example for standard reporting is shown in Appendix A-5. In the example some manual adjustments have been made to the excel-sheet produced from *MEMW.xls*. These are mainly for the presentation of the pie chart that originally shows percent contribution of maximum EIF for all components in the discharge. We adjust this to be able to show percentage contribution of time-averaged EIF and grouping of the NOS, see Appendix A, Figure A 1.

5 Abbreviations

Abbreviation	Full description	Explanation / definition/reference
BTEX	Benzene, Toluene, Ethylbenzene and Xylene	Collection of the monoaromatic substances
EIF	Environmental Impact Factor	Indicator for environmental risk of produced water discharges developed and applied on NCS to report progress towards the goal of zero harmful discharge. EIF corresponds to a volume of water where msPAF (calculated using PNEC levels derived using EU guidance) exceeds 5%, expressed in multiples of 100 000 m ³ (100 m x 100 m x 10 m depth cuboids)
EC	European Commission	http://ec.europa.eu/index_en.htm
DREAM	Dose-Related Risk and Effect Assessment Model	
LC50/EC50	Median lethal/effect concentration	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 (LC _x) or the effect concentration (EC _x), 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).
ECHA	European Chemicals Agency	http://echa.europa.eu/
HOCNF	Harmonised Offshore Chemical Notification Format	https://www.ospar.org/documents?v=33043
Koc	Organic carbon to water partition coefficient	This parameter can be estimated based on info in the HOCNF scheme. A calculator implemented in DREAM can estimate the KOC factor, given log Pow.
MEG	Monoethylenglycol	Production chemical listed as PLONOR.
MEMW	Marine Environmental Modelling Workbench	The model frame for DREAM.
msPAF	multiple substance Potentially Affected Fraction	Combination of different PAF values into overall risk indicator.
NCS	Norwegian Continental Shelf	
NOEC	No Observed Effect Concentration	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/EC _x (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.
NOROG	The Norwegian Oil and Gas Association	https://www.norskoljeoggass.no/en/ Offshore Norge from August 2022



NOS	Naturally occurring substances	Substances derived from the oil/gas reservoir that are found in the produced water stream. Examples include heavy metals and components of oil. May also be known as geogenic chemicals or naturally occurring substances.
OIC	Offshore Industry Committee	Committee under OSPAR
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic	https://www.ospar.org/
PAF	Potentially Affected Fraction	Likelihood of a randomly selected species in the distribution to be affected above a defined effect level.
PAH	Polycyclic Aromatic Hydrocarbons	A chemical class of substances that are present in produced water, some of which are carcinogenic.
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.
Pow	Octanol/water partition coefficient	“Pow” is equivalent to Kow and means the partition coefficient of a substance between octanol and water, measured or calculated provided in the HOCNF.
PW	Produced Water	Is the associated water produced with oil and gas from a reservoir.
RBA	Risk-Based Approach	Approach for the management of PW discharges from offshore installations as proposed by the OIC (08/13/1-E). Recommendations and Guidelines adopted by OSPAR in 2012 (OSPAR Agreement: 2012-7).



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A-1. Input-data to EIF calculations

Table A 1 Field information.

Field name		Release depth (m below sea surface)	
Region		PW release rate m ³ /year	
Position (lat/long)		PW release rate m ³ /day	

Table A 2 Input on discharge concentration of NOS in PW.

Substances	Concentrations (mg/L)
Benzene	
Toluene	
Ethylbenzene	
Xylene	
Naphthalenes	
Acenaphthene	
Acenaphthylene	
Fluorene	
Anthracene	
Phenanthrene incl. substitutes	
Dibenzothiophene incl. substitutes	
Fluoranthene	
Pyrene	
Benz(a)anthracene	
Chrysene	
Dibenzo(a-h) anthracene	
Benzo(g-h-i) perylene	
Benzo(a)pyrene	
Benzo(k)fluoranthene	
Indeno(1-2-3-cd) pyrene	
Benzo(b)fluoranthene	
Phenol (C0-C3-alkyl-phenols)	
Butylphenol (C4-alkyl-phenols)	
Pentylphenol (C5-alkyl-phenols)	
Octylphenol (C6-C8-alkyl-phenols)	
Nonylphenol (C9-alkyl-phenols)	
Dispersed-oil	
Arsenic	
Cadmium	
Chromium	
Copper	
Nickel	
Mercury	
Lead	
Zinc	

Concentration of natural substances in PW should be taken from the latest results, the average of biannual samples from chemical characterisation of PW samples, according to the Norwegian Oil and Gas Guidelines (NOROG, 2013).

Table A 3 HOCNF information required for added chemicals on individual substance level.

Chemical name	Discharge concentration (mg/L)	Density	Bioaccumulation potential (Log Pow)*	Biodegradation (%) 28 days**	PNEC (µg/L) ***

* Highest value

** Lowest value, measured at 20 °C.

*** PNEC determined based on lowest median lethal/effect concentration value (LC/EC50) divided by the assessment factor of 1 000 if acute toxicity data is available only.

A-2. Naturally Occurring Substances in PW and their grouping into EIF groups

Table A 4 The table shows the NOS in the PW, and grouping used when reporting pie-charts.

BTEX	<ul style="list-style-type: none"> • Benzene • Toluene • Ethylbenzene • Xylene
Naphthalenes	<ul style="list-style-type: none"> • Naphthalene • C1-Naphthalenes C2-Naphthalenes C3-Naphthalenes
PAH 2-3 ring	<ul style="list-style-type: none"> • Total 2-3-ring e.g., <ul style="list-style-type: none"> ○ Acenaphthylene ○ Acenaphthene ○ Fluorene ○ Phenanthrene, including C1-C3 alkylhomologues ○ Anthracene (and Dibenzothiophenes, including C1-C3 alkylhomologues)
PAH 4 ring	<ul style="list-style-type: none"> • Total 4-ring e.g., <ul style="list-style-type: none"> ○ Fluoranthene ○ Pyrene ○ Chrysene ○ Benz(a)anthracene
PAH 5-6 ring	<ul style="list-style-type: none"> • Total 5-6 ring e.g., <ul style="list-style-type: none"> ○ Dibenzo(ah)anthracene ○ Benzo(a)pyrene ○ Benzo(ghi)perylene ○ Benzo(b)fluoranthene ○ Benzo(k)fluoranthene ○ Indeno(123,cd)pyrene
Phenol C0-C3	<ul style="list-style-type: none"> • Phenol • C1-Phenols <ul style="list-style-type: none"> ○ o-cresol ○ m-cresol ○ p-cresol • C2-Phenols <ul style="list-style-type: none"> ○ 2,5-Xylenol ○ 3,5-Xylenol ○ 2,4-Xylenol ○ 4-Ethylphenol other C2-phenol alkylhomologues defined by analytical method* • C3-Phenols <ul style="list-style-type: none"> ○ 2-n-Propylphenol ○ 2.3.5-Trimethylphenol ○ 4-n- Propylphenol ○ 2.4.6-Trimethylphenol • other C3-phenol alkylhomologues defined by analytical method*
Phenol C4	<ul style="list-style-type: none"> • C4-Phenols <ul style="list-style-type: none"> ○ 4-tert-Butylphenol ○ 4-iso-Propyl-3-Methylphenol



	<ul style="list-style-type: none"> ○ 4-n-Butylphenol ○ other C4-phenol alkylhomologues defined by analytical method*
Phenol C5	<ul style="list-style-type: none"> • C5-Phenols <ul style="list-style-type: none"> ○ 2-tert-Butyl-4-Methylphenol ○ 4-tert-Butyl-2-Methylphenol ○ 4-n-Pentylphenol ○ other C5-phenol alkylhomologues defined by analytical method*
Phenol C6-8	<ul style="list-style-type: none"> • C6-Phenols <ul style="list-style-type: none"> ○ 4-n-hexylphenol ○ 2,6-Di-iso-Propylphenol ○ 2,5-Di-iso-Propylphenol ○ 2-tert-Butyl-4-Ethylphenol ○ 6-tert-Butyl-2,4-Dimethylphenol • C7-Phenols <ul style="list-style-type: none"> ○ 4-n-Heptylphenol ○ 2,6-dimethyl-4-(1,1-dimethylpropyl)phenol ○ 4-(1-ethyl-1-methylpropyl)-2-methylphenol ○ (2,6-diisopropyl-4-methylphenol) • C8-Phenols <ul style="list-style-type: none"> ○ 2,4-Di-tert-Butylphenol ○ 4-tert-Octylphenol ○ 2,6-Di-tert-Butylphenol ○ 4-n-Octylphenol
Phenol C9	<ul style="list-style-type: none"> • C9-Phenols <ul style="list-style-type: none"> ○ 4-n-Nonylphenol ○ 2-Methyl-4-tert-Octylphenol ○ 2,6-Di-tert-Butyl-4-Methylphenol ○ 4,6-Di-tert-Butyl-2-Methylphenol
Dispersed oil	

*See Offshore Norge (Norwegian Oil and Gas) Guidelines for chemical characterization of PW for further details on alkylated phenols (NOROG, 2013).



A-3. PNEC values for naturally occurring substances

Table A 5 PNECs established NOS typically analysed in PW (OSPAR, 2014). The list of OSPAR PNEC will be updated regularly and can be found on the OSPAR OIC website.

Substance	PNEC (µg/L)	Source ³	Additional information
BTEX			
Benzene (and xylene)	8	EC, 2013	It is proposed to apply the PNEC for benzene to represent the toxicity of xylene
Toluene	7.4	EU RAR, 2003	
Ethylbenzene	10	EU RAR, 2007	
Naphthalenes			
Naphthalene (and alkyl homologues)	2	EC, 2013	It is proposed to apply the PNEC for naphthalene to represent the toxicity of C1-C3 alkyl homologues of naphthalene
Polycyclic aromatic hydrocarbons (PAHs)			
2-3 ring PAH			
Acenaphthene	0.38	EU RAR CTPHT, 2008	
Acenaphthylene	0.13	EU RAR CTPHT, 2008	
Fluorene	0.25	EU RAR CTPHT, 2008	
Anthracene (and dibenzothiophene and alkyl homologues)	0.1	EC, 2013	It is proposed to apply the PNEC for anthracene to represent the toxicity of dibenzothiophene and C1-C3 alkyl homologues of dibenzothiophene
Phenanthrene (and alkyl homologues)	1.3	EU RAR CTPHT, 2008	It is proposed to apply the PNEC for phenanthrene to represent the toxicity of C1-C3 alkyl homologues of phenanthrene
4 ring PAHs			
Fluoranthene	0.01 ¹	EU RAR CTPHT, 2008	Operators on NCS deviate from OSPAR PNECs (2014), PNEC values (µg/L) based on ecotoxicity data rather than health effects from consumption of PAH contaminated fishery products.
Pyrene	0.023	EU RAR CTPHT, 2008	
Benz(a)anthracene	0.0012	EU RAR CTPHT, 2008	
Chrysene	0.007	EU RAR CTPHT, 2008	
5-6 ring PAHs			
Dibenzo(a,h)anthracene	0.00014	EU RAR CTPHT, 2008	



Benzo(a)pyrene	0.022 ¹	EU RAR CTPHT, 2008	Operators on NCS deviate from OSPAR PNECs (2014), PNEC values (µg/L) based on ecotoxicity data rather than health effects from consumption of PAH contaminated fishery products.
Benzo(g,h,i)perylene,	0.00082 ¹		
Benzo[b]fluoranthene,	0.017 ¹		
Benzo[k]fluoranthene	0.017 ¹		
Indeno[1,2,3-cd]pyrene)	0.00027 ¹		
Dispersed oil			
Dispersed oil	70.5	Smit et al., 2009	No official standard available
Alkyl phenols			
Phenol (and C1-C3 alkyl phenols)	7.7	EU RAR, 2006	Reliable PNECs are not available for individual C0-C3 alkyl phenols. It is proposed to apply the PNEC for phenol to represent the toxicity of all C0-C3 alkyl phenols
Butylphenol (and other C4 alkyl phenols)	0.64	EU RAR, 2008	Reliable PNECs are not available for individual C4 alkyl phenols. It is proposed to apply the PNEC for butylphenol to represent the toxicity of all C4 alkyl phenols
Pentylphenol (and other C5 alkyl phenols)	0.2	EU RAR, 2008	Reliable PNECs are not available for individual C5 alkyl phenols. It is proposed to apply the PNEC for pentylphenol to represent the toxicity of all C5 alkyl phenols
Octylphenol (and C6-C8 alkyl phenols)	0.01	EC, 2013	Reliable PNECs are not available for individual C6-C8 alkyl phenols. It is proposed to apply the PNEC for octylphenol to represent the toxicity of all C6-C8 alkyl phenols
Nonylphenol (and other C9 alkyl phenols)	0.3	EC, 2013	Reliable PNECs are not available for individual C9 alkyl phenols. It is proposed to apply the PNEC for nonylphenol to represent the toxicity of all C9 alkyl phenols
Metals			
Arsenic	0.6 +Cb ²	UKTAG, 2007	No EU standard available
Cadmium	0.2+Cb ²	EC, 2013	
Chromium	0.6+ Cb	UKTAG, 2007	No EU standard available
Copper	2.6	EU RAR, 2008	
Nickel	8.6 +Cb	EC, 2013	
Mercury	0.05+Cb ²	WFD, 2008	The PNEC does not account for bioaccumulation
Lead	1.3	EC, 2013	
Zinc	3.4+Cb ²	UKTAG, 2012	

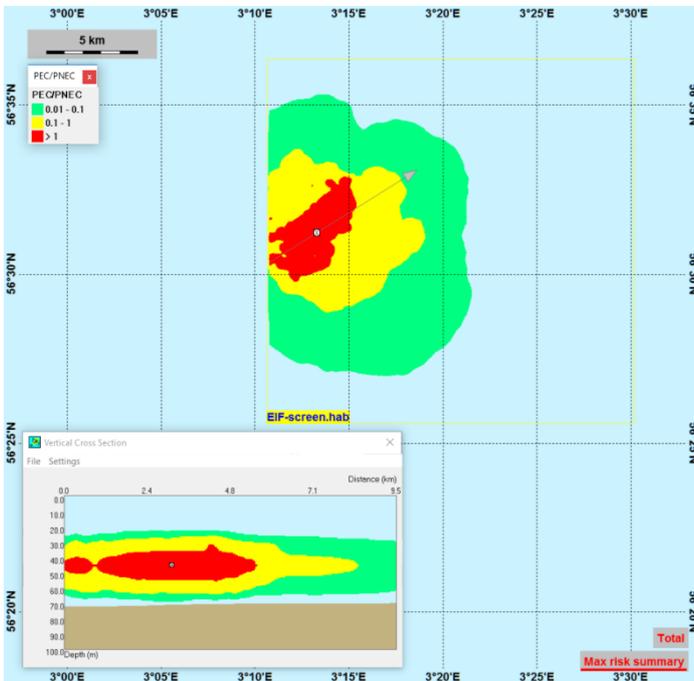
¹ PNECs for fluoranthene and the 5-6 ring PAHs: Benzo[b]fluoranthene, benzo(a)pyrene, benzo[k]fluoranthene and indeno[1,2,3-cd]pyrene and benzo(g,h,i)perylene applied by operators on NCS deviate from OSPAR PNECs (2014) and are based on ecotoxicity data rather than health effects from consumption of PAH contaminated fishery products.

² Cb: Background concentration (µg/L). Site specific background concentrations are preferred. If not available, ranges for background concentrations can be found in the OSPAR background document (OSPAR, 2004).

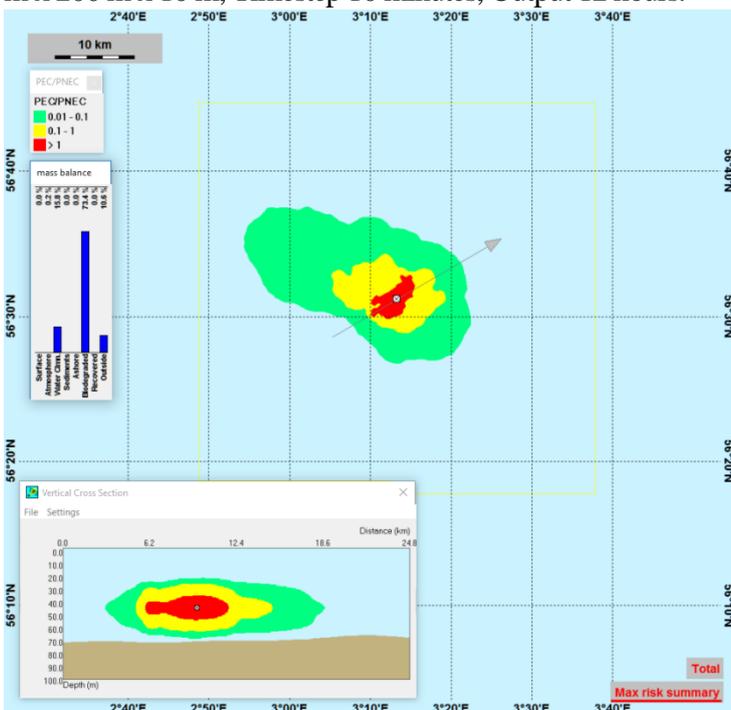
³ See sources in PNECs established for naturally occurring substances typically analysed in produced water (OSPAR, 2014).

A-4. Example applications for EIF screening

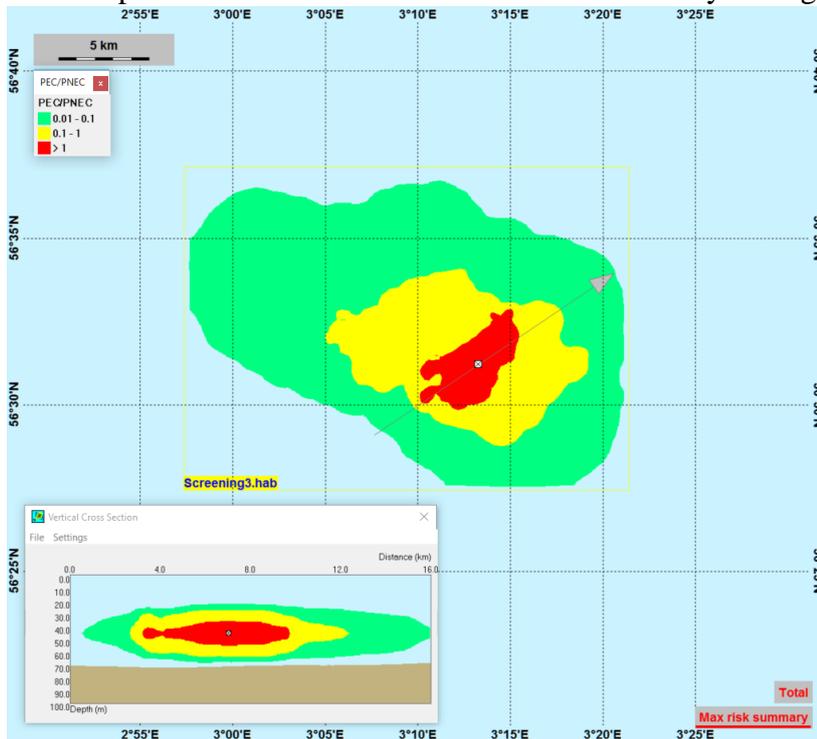
Example 1: The risk field nears or intersects the boundary of the grid. Increase the grid to cover the entire area with $PEC/PNEC > 1$, plus additional area beyond where the risk intersected the grid boundary. Grid resolution for concentration grid used in the example: 200 m x 200 m x 10 m, Timestep 10 minutes, Output 12 hours.



Example 2: The risk field is well within the grid. Mass balance shows that 10.6% of the lowest concentrations is outside grid, these concentrations are too low to contribute to risk. Decrease the grid to fit the outer boundary of the risk ($PEC/PNEC$) field. Grid resolution for concentration grid used in the example: 200 m x 200 m x 10 m, Timestep 10 minutes, Output 12 hours.



Example 3: Edit the grid boundary to fit to the risk (PEC/PNEC) field. Grid area 24 km x 18 km.
 Increase the resolution for the concentration grid to 100 m x 100 m x 10 m, Timestep 10 minutes, Output 12 hours. Repeat the simulation 5 times to determine the stability of the grid.

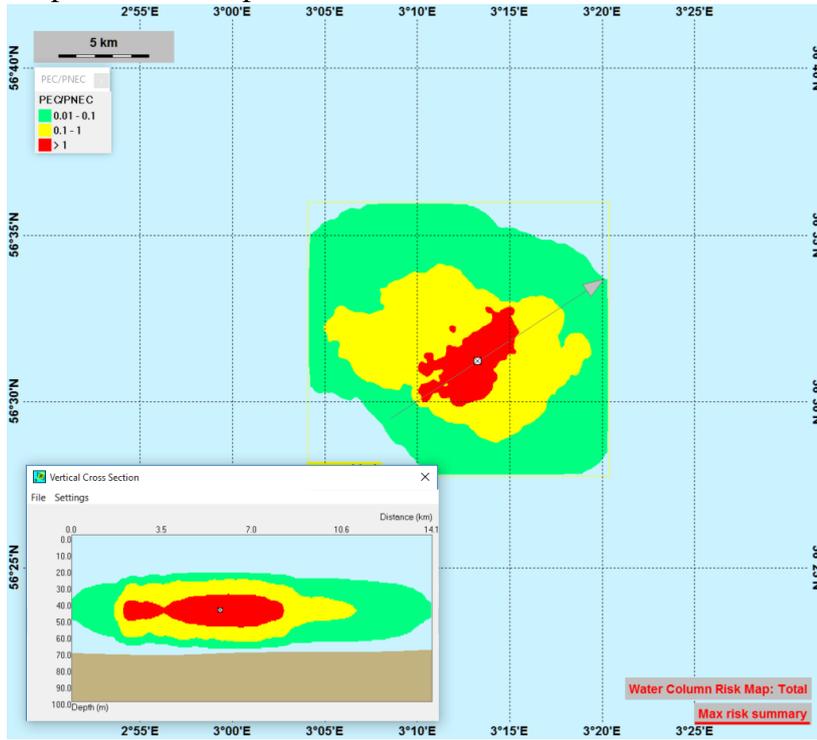


	Maximum EIF	Timeaveraged EIF
Run 1	143	81
Run 2	139	81
Run 3	130	80
Run 4	125	83
Run 5	130	82

The risk key shows PEC / PNEC down to 0.01, the green area, which corresponds to 0.03% risk, see Table A 6. This means that there are no concentrations in the green area that contributes to risk. One can therefore limit the grid even a little more without removing any contribution to the EIF. See screening 4.



Example 4: Increase the grid to cover entire red and yellow area, and some of the green PEC/PNEC area. **Grid area 15 km x 16 km.** Resolution for the concentration grid 100 m x 100 m x 10 m, Timestep 10 minutes, Output 12 hours. Repeat the simulation 5 times to determine the stability of the grid.



	Maximum EIF	Timeaveraged EIF
Run 1	139	82
Run 2	134	81
Run 3	145	82
Run 4	137	82
Run 5	134	80

By this screening exercise you ensure that the concentrations of individual substances that contributes to the risk (EIF) are not outside of your defined grid area, then consider whether you can decrease the grid. The grid area should always cover the entire red and yellow area, and to some extend the green area.

Table A 6 Table showing correspondence between the PEC/PNEC and Risk % key.

Key	PEC/PNEC	Risk %
Green	0.01 – 0.1	0.03 – 0.378
Yellow	0.1 – 1	0.378 - 5
Red	> 1	> 5

A-5. Example of standard reporting from MEMW.xls for EIF PW

Table A 7 Table showing time averaged and maximum EIF for the water column.

Computed max. EIF:	134						
Time averaged EIF:	81						
Components	Product	Rel.Tons/day	Concentration ppm	PNEC ppb	Contribution to risk	Contribution max EIF	Contribution Timeaveraged EIF
Total		21138					
Benzene			12.5	8	22.5	30.15	18.2250
Toluene			4.133	7.4	7.19	9.6346	5.8239
Ethylbenzene			0.09	10	0.07	0.0938	0.0567
Xylene			0.6733	8	0.85	1.139	0.6885
Napthalene			0.324667	2	4.25	5.695	3.4425
Acenaphthene			0.000315	0.38	0.03	0.0402	0.0243
Acenaphthylene			0.000175	0.13	0.05	0.067	0.0405
Fluorene			0.002883	0.25	0.57	0.7638	0.4617
Anthracene			0.00004	0.1	0.01	0.0134	0.0081
Phenanthrene_incl_substitutes			0.026283	1.3	1.07	1.4338	0.8667
Dibenzothiophene_incl_substitutes			0.005252	0.1	3.15	4.221	2.5515
Fluoranthene			0.000035	0.01	0.14	0.1876	0.1134
Pyrene			0.000208	0.023	0.5	0.67	0.4050
Benz(a)anthracene			0.000025	0.0012	1.28	1.7152	1.0368
Chrysene			0.000122	0.007	1.05	1.407	0.8505
Dibenzo(a-h)anthracene			0.000007	0.00014	3.45	4.623	2.7945
Benzo(g-h-i)perylene			0.000028	0.00082	2.24	3.0016	1.8144
Benzo(a)pyrene			0.000005	0.022	0.01	0.0134	0.0081
Benzo(k)fluoranthene			0.000005	0.017	0.01	0.0134	0.0081
Indeno(1-2-3-cd)pyrene			0.00001	0.00027	2.46	3.2964	1.9926
Benzo(b)fluoranthene			0.000043	0.017	0.11	0.1474	0.0891
Phenol(C0-C3-alkyl-phenols)			7.0133	7.7	25.13	33.6742	20.3553
Butylphenol(C4-alkyl-phenols)			0.076167	0.64	9.2	12.328	7.4520
Pentylphenol(C5-alkyl-phenols)			0.011333	0.2	3.12	4.1808	2.5272
Octylphenol(C6-C8-alkyl-phenols)			0.000284	0.01	1.82	2.4388	1.4742
Nonylphenol(C9-alkyl-phenols)			0.00009	0.3	0.01	0.0134	0.0081
Dispersed-oil			8.79	70.5	9.32	12.4888	7.5492
Arsenic			0.001433	0.6	0.11	0.1474	0.0891
Cadmium			0.000068	0.21	0.01	0.0134	0.0081
Chromium			0.001933	0.6	0.15	0.201	0.1215
Copper			0.00057	2.6	0.01	0.0134	0.0081
Nickel			0.000575	8.6	0	0	0
Mercury			0.000107	0.048	0.1	0.134	0.0810
Lead			0.000138	1.3	0	0	0
Zinc			0.0032	3.4	0.04	0.0536	0.0324

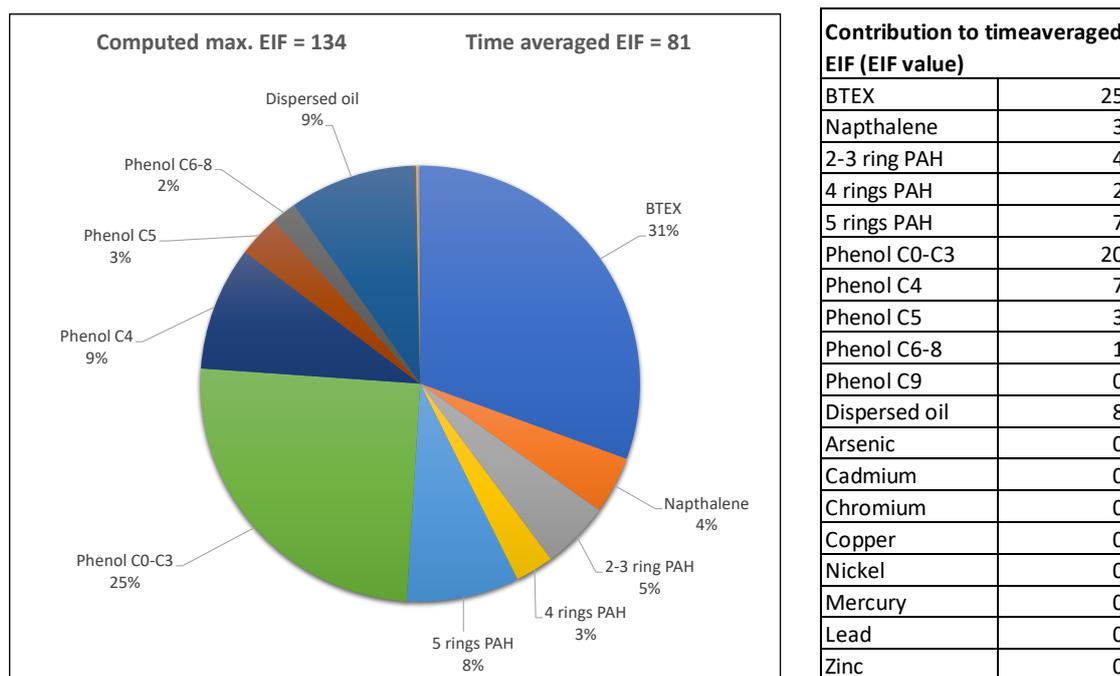


Figure A 1 Pie-chart showing time averaged and maximum EIF for the water column (grouping of substances to the right).

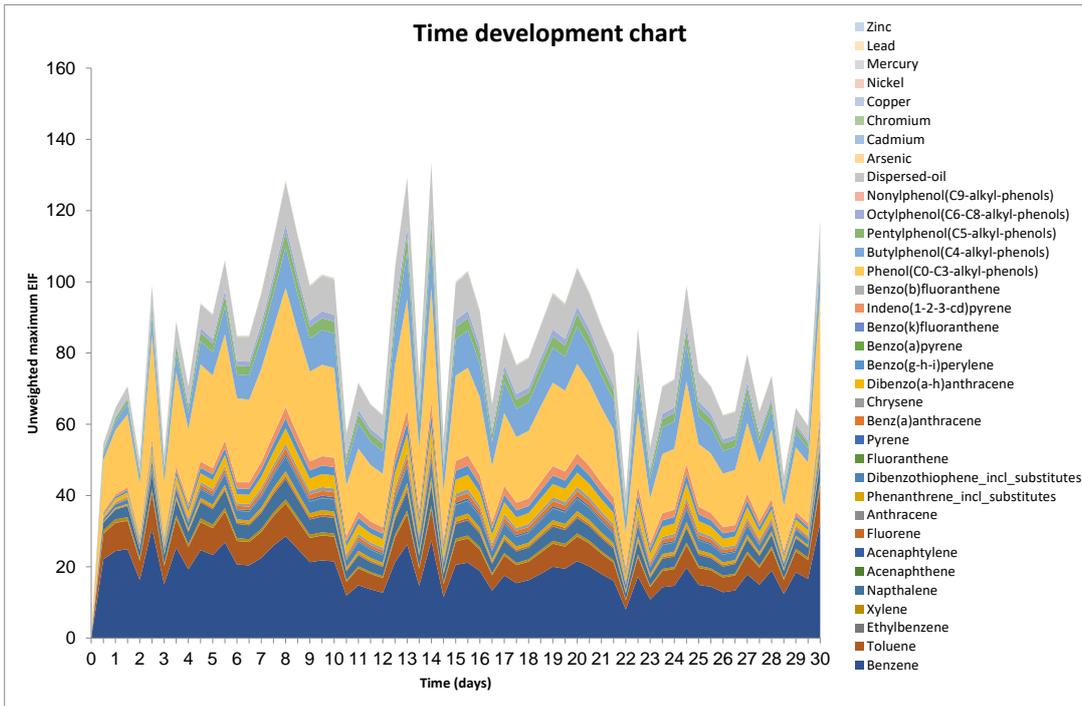


Figure A 2 Time development of maximum EIF for the water column.

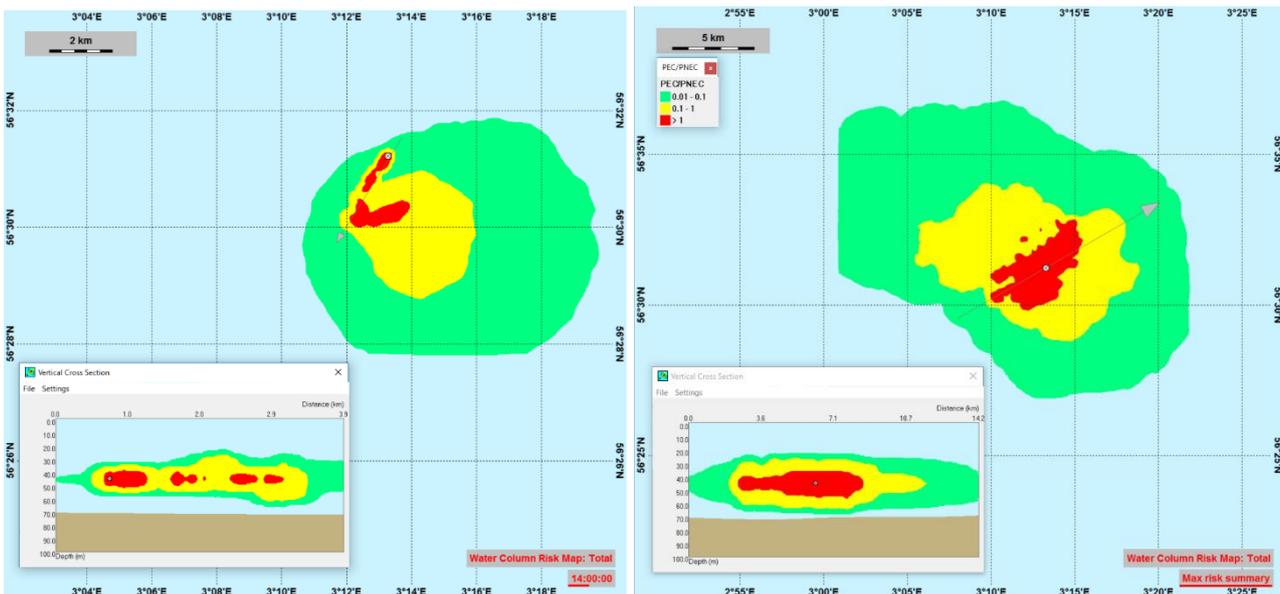


Figure A 3 A) Shows snapshot for the time-step with maximum risk over 5% (PEC/PNEC > 1) during the simulation period.
 B) Shows the accumulated maximum EIF for each grid cell through the whole water-column throughout the simulation period (footprints from all time steps).



A-6. Data on physical and chemical properties of natural substances in PW

Table A 8: Data on physical and chemical properties of NOS in PW (Data collected from <https://pubchem.ncbi.nlm.nih.gov/>, PNECs from OSPAR 2014).

CHEM_NAME	MOLWT (g/mol)	DENSITY (kg/L)	SLBLTY (mg/L)*	VAPPRS 25° C (atm)	Log Pow	Koc	PNEC (µg/L)
Benzene	78.11	0.879	-	0.1247368	2.13	134.896	8
Toluene	92.14	0.867	-	0.0373684	2.73	537.032	7.4
Ethylbenzene	106.16	0.867	-	0.0126316	3.15	1412.54	10
Xylene	106.16	0.86	-	0.0116316	3.15	1412.54	8
Naphthalenes	128.17	1.16	-	0.0001118	3.3	1995.26	2
Acenaphthene	154.21	1.2	-	0.0000029	3.92	8317.64	0.38
Acenaphthylene	152.19	0.8988	-	0.0000063	3.94	8709.64	0.13
Fluorene	166.22	1.203	-	0.0000008	4.18	15135.6	0.25
Anthracene	178.23	1.24	-	0.0000008	4.45	28183.8	0.1
Phenanthrene_incl_substitutes	178.23	1.025	-	0.000000159	4.46	28840.3	1.3
Dibenzothiophene_incl_substitutes	184.26		-	0.000000270	4.38	23988.3	0.1
Fluoranthene	202.25	1.252	-	0.000000121	5.16	144544	0.01
Pyrene	202.25	1.27	-	0.00000001	4.88	75857.8	0.023
Benz(a)anthracene	228.3	1.27	-	0.0000000003	5.76	575440	0.0012
Chrysene	228.3	1.274	-	0.00000000001	5.81	645654	0.007
Dibenzo(a-h)anthracene	278.3	1.282	-	0.0000000	6.75	5.62E+06	0.0001
Benzo(a)pyrene	252.3	1.4	-	0.0000000	6.13	1.35E+06	0.022
Benzo(b)fluoranthene	252.3		-	0.0000000	5.78	602560	0.017
Benzo(k)fluoranthene	252.3		-	0.0000000	6.11	1.29E+06	0.017
Benzo(g-h-i)perylene	276.3	1	-	0.0000000	6.63	4.27E+06	0.0008
Indeno(1-2-3-cd)pyrene	276.3		-	0.0000000	6.58	3.80E+06	0.0003
Phenol(C0-C3-alkyl-phenols)	94.11	1.07	-	0.0001447000	1.46	187	7.7
Butylphenol(C4-alkyl-phenols)	150.22	0.98	-	0.0000013160	3.29	4365	0.64
Pentylphenol(C5-alkyl-phenols)	164.24	0.96	-	0.0000000106	6.18	1514000	0.2
Octylphenol(C6-C8-alkyl-phenols)	206.32	0.95	-	0.0000000106	4.8	1	0.01
Nonylphenol(C9-alkyl-phenols)	220.35	0.94	-	0.0000000106	5.8	1	0.3
Dispersed oil	212.079	1.2	-	0.0045500000	0.305566	2.021	70.5
Copper (Cu)	63.54	8.92	-	0	-	-	2.6
Zinc (Zn)	65.38	7.14	-	0	-	-	3.4
Nickel (Ni)	58.71	8.9	-	0	-	-	8.6
Lead (Pb)	207.2	11.34	-	0	-	-	1.3
Cadmium (Cd)	112.41	8.642	-	0	-	-	0.21
Mercury (Hg)	200.59	13.59	-	0	-	-	0.048
Chromium (Cr)	63.546	7.15	-	0	-	-	0.6
Arsenic (As)	63.546	5.73	-	0	-	-	0.6

* **SLBLTY, solubility:** The EIF for PW considers the fully dissolved fraction of substances. To achieve this in simulations, 1000 mg/L should be used as default value."



A-7. Biodegradation

Table A 9: Standard biodegradation rates for naturally occurring substances/substance groups at 13°C. Results are shown as primary (Prim) and ultimate (Ult) biodegradation. For references to the data, see Brakstad et al. (2021).

Main group	Representative substance	Biodegradation ½ life (days)		First-order rate coefficient (k-values)	
		Prim	Ult	Prim	Ult
EIF-BTEX	Benzene	10	14	0.0693	0.0494
	Toluene	8	9	0.0844	0.0799
	Ethylbenzene	7	12	0.1024	0.0585
	Xylene	9	17	0.0761	0.0407
EIF-Naphthalenes	Naphthalene	4	24	0.1844	0.0286
EIF-PAH 2-3 ring	Acenaphthene	12	59	0.0603	0.0118
	Acenaphthylene	22	113	0.0312	0.0061
	Fluorene	5	24	0.1471	0.0289
	Anthracene	12	59	0.0601	0.0118
	Phenanthrene	9	37	0.0803	0.0190
	Dibenzothiophene	8	40	0.0874	0.0174
EIF-PAH 4 ring	Fluoranthene	14	69	0.0510	0.0100
	Pyrene	21	106	0.0333	0.0065
	Benz[a]anthracene	15	78	0.0454	0.0089
	Chrysene	22	112	0.0317	0.0062
EIF-PAH 5-6 ring	Dibenzo[a,h]anthracene	212	>450*	0.0033	0.00015*
	Benzo[a]pyrene	28	144	0.0245	0.0048
	Benzo[b]fluoranthene	23	115	0.0307	0.0060
	Benzo[k]fluoranthene	256	>450*	0.0027	0.00015*
	Benzo[g,h,i]perylene	>450*	>450*	0.0015*	0.00015*
	Indeno[1,2,3-cd]pyrene	>450*	>450*	0.0015*	0.00015*
Phenols	Phenol C0-C3 -Phenol	2	7	0.4993	0.0979
	Phenol C4 -Butylphenol**	23	116	0.0304	0.0060
	Phenol C5 -Pentylphenol**	18	119	0.0381	0.0058
	Phenol C6-C8 -Octylphenol**	17	57	0.0406	0.0121
	Phenol C9 -Nonylphenol	11	34	0.0606	0.0201
	Dispersed oil	18	166	0.0392	0.0042
EIF-Copper (Cu)		No degradation		0,0000001	
EIF-Zinc (Zn)		No degradation		0,0000001	
EIF-Nickel (Ni)		No degradation		0,0000001	
EIF-Lead (Pb)		No degradation		0,0000001	
EIF-Cadmium (Cd)		No degradation		0,0000001	
EIF-Mercury (Hg)		No degradation		0,0000001	
EIF-Chromium (Cr)		No degradation		0,0000001	
EIF-Arsenic (As)		No degradation		0,0000001	
Offshore chemicals****	Field-specific	HOCNF (BOD 28d)			

* Assuming <10% degradation at the end of a test period of 71 days.

** Mean values of n-alkylated and tert-alkylated phenols.

**** Preferably on individual substance level.

The biodegradation rates in DREAM for naturally occurring substances are described as k-values by first-order rates by non-linear regression calculations from Equation 1:

$$k[A] = d[A]/d_{\text{time}} \quad \text{Equation 1}$$

Exceptions from this calculation are naturally occurring substances with <10% degradation at the end of test periods. For these substances are k-values described by Equation 2.

The biodegradation rates in DREAM for added chemicals are described as k-values from Equation 2:

$$k = -(1/\text{time}) * \ln((100 - \% \text{ BOD}) / 100) \quad \text{Equation 2}$$

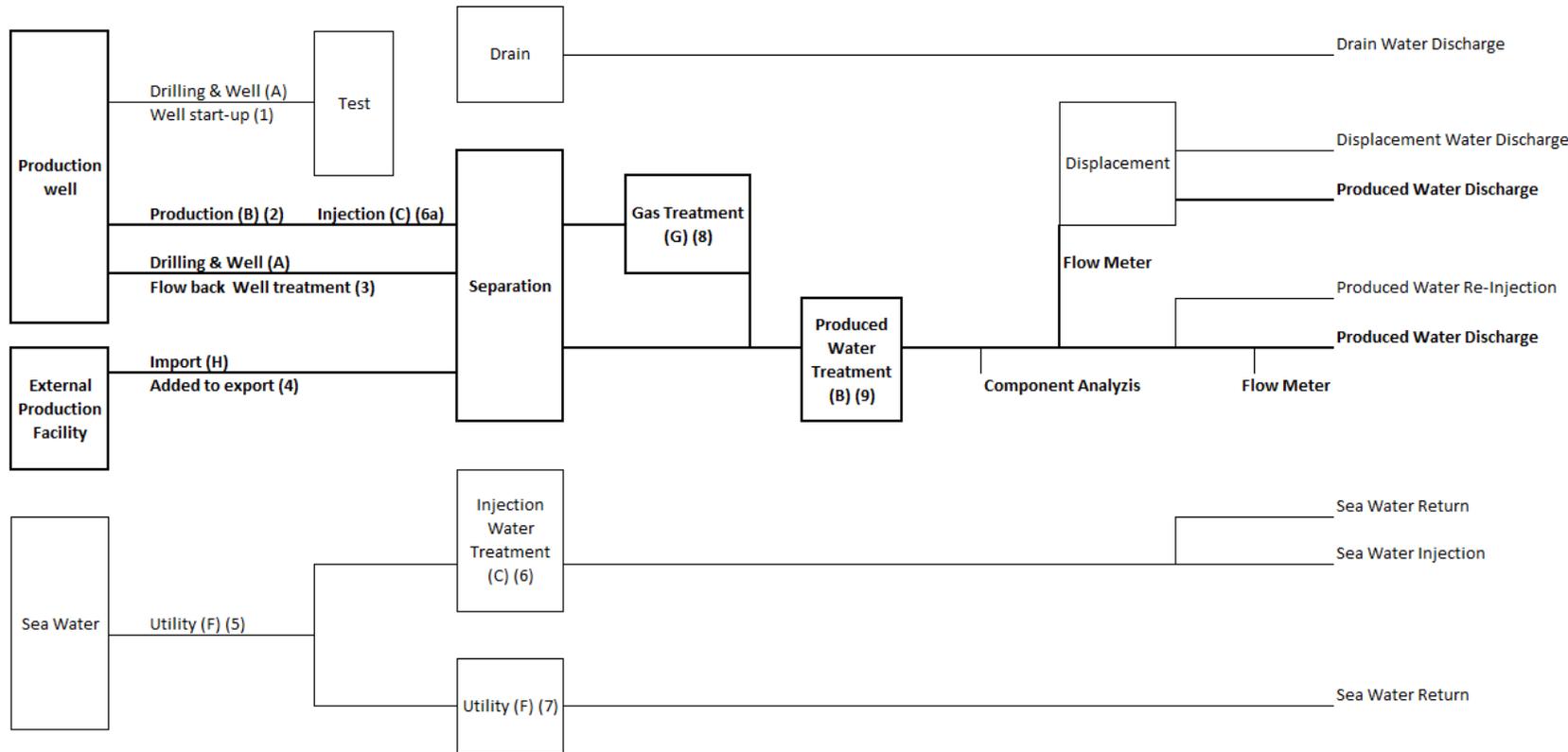
where; time is usually 28 days (standard test conditions)

Biodegradation rates are assumed by the model to have been determined at a temperature of 13°C (T_{ref}). The model uses a Q10 scaling approach ($Q_{10} = 2$) to transform the rates to the actual water temperature (T) in a simulation:

$$k(T) = k(T_{ref})Q_{10}^{(T-T_{ref})/10^{\circ}\text{C}}$$



A-8. Flow chart of offshore chemical discharge streams



Preconditions:

- EIF-calculation as required in Activity Regulation §60 and reported to NEA applies only to Produced Water

The flow chart:

- All in bold boxes, lines and text shall be included in EIF Produced Water
- Letters in brackets refer to NOROG 044, table 14
- Numbers in brackets refer to chemicals added in specific water or fluid stream (see text box below)

Added chemicals:

- (1) Completion chemicals
- (2) Emulsion Braekers; Defoamers; Scale Inhibitors; H2S-scavengers
- (3) Scale Inhibitors; Scale Dissolvers; Acids; Corrosion Inhibitors; Biocide
- (4) Corrosion Inhibitors; Hydrate Inhibitors
- (5) Hypochlorite (Biocide)
- (6) Biocide
- (6a) Biocide (Produced back with PW)
- (7) Biocide
- (8) TEG; H2S-scavenger
- (9) Flocculant



A-9. Obtaining wind and current data

The NorShelf netCDF datafiles for May 2020 can be downloaded from a THREDDS server operated by the Norwegian Meteorological Institute². There are 31 files to be downloaded, each containing data for a single day:

https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200501T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200502T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200503T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200504T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200505T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200506T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200507T00Z.nc
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https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200511T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200512T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200513T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200514T00Z.nc
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https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200517T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200518T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200519T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200520T00Z.nc
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https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200530T00Z.nc
https://thredds.met.no/thredds/fileServer/sea_norshelf_files/norshelf_qck_ZDEPTHs_an_20200531T00Z.nc

The ERA5 wind data files for May 2020 can be downloaded from Copernicus³. The data are free to download, but a user account is required, which can be created on the site. Once logged in, select the two wind variables **10m u-component of wind** and **10m v-component of wind**, year 2020, month of May, and all days and times. Either the full global coverage, or a subset covering the NCS can be selected under “Geographical Area”. Finally, select the netCDF format, and click the Submit button. The system then prepares the dataset (may take some minutes), after which a download link appears. Click this link to download the dataset.

² https://thredds.met.no/thredds/catalog/sea_norshelf_files/catalog.html

³ <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form>