Environmental risk assessment of biocides applied in the offshore oil exploration industry

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Cover note

Underlying document contains a proposal for the evaluation of PT11/PT12 off shore uses with four questions we would like to find agreement on. This document was introduced and discussed during TMIV-2014, and member states were able to send their comments before the 20th of December 2013. Responses were received from DK and SE. Their responses are included in the current document.

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Introduction

PT12 application of biocides may concern the application in the offshore oil exploration industry to prevent obstructions in piping systems, removal of biofilms, controlling sulphur dioxide production by bacteria, and/or preservation of drilling mud. These biocides are predominantly discharged to the open sea. Although various models are available to assess their environmental fate, for example EUSES in which preservation of drilling fluids is included and CHARM (Chemical Hazard Assessment and Risk Management) for various oil platform applications, some applications that require vast amounts of biocides, for instance oil storage in gravity based systems, are not covered. Moreover, the current existing models are not considered representative as they assume an average depth of 150 m, while Europe's major oil fields are located in the shallow parts of North Sea that vary between 10 and 50 m[1]. The MAMPEC-model (Marine Antifouling Model to Predict Environmental Concentration), which was initially developed to asses the environmental impact of antifouling paints on ship hulls, is considered more realistic regarding water depths and flow velocities. Moreover, the model is generally adopted for risks assessment of antifouling paints and applied for other marine applications (i.e. impregnated fish nets) as well.

The current document provides additional scenarios for emission from oil storage tanks, reservoir injection, and closed drain systems. Because the emission is based on a single platform, while an oil field may house various installations, this document also describe how MAMPEC can be used in order to derive background concentrations and how the final PEC for the marine environment are calculated.

Oil storage in gravity based structures

Oil platforms are usually founded on gravity based structures (GBS), a hollow concrete construction that is filled with water once the platform arrived at the oil field and therefore sinks to the seafloor. Oil that is extracted from the produced water is usually stored in tanks located in the GBS with a volume up to 20000 m³. Because the GBS has to be filled with fluids continuously in order to maintain the platform's stability, the tanks are completely filled with water to which biocides are added to prevent biofilms on the tank's interior surface and microbial growth in the aqueous phase. During oil exploration the water is gradually

[1] http://www.noordzeeatlas.nl/Kaart/waterdiepte.htm

displaced by oil and discharged overboard. During offloading to a tanker the oil is replaced by water again.

Except for a short break during offloading to oil tankers, biocides are continuously released from the storage tanks as oil is continuously pumped from the earth's crust as well. The amount of water per platform displaced daily to the open sea is 2000 m³, a default that was taken from CHARM (average daily oil production per platform). The emission is subsequently calculated by:

$$E_{local} = V_{displaced\ water} \cdot C_{GBS} \qquad (1$$

where:

–	E_{local}	daily emission from one platform to the open sea per platform (g/d)	O
–	$V_{displaced\ water}$	volume of the water displaced daily (2000 m³/d)	D
–	C_{GBS}	the concentration of the active substance in the GBS according to the instructions of use (mg/L)	S

Reservoir injection

In order to increase oil extraction efficiency, water is injected into the bedrock reservoir during oil exploitation and pumped up again along with oil (produced water). On board oil and water are separated and the aqueous phase is discharged overboard. Biocides are added to the injection fluid to control sulphur reducing bacteria and thereby avoiding the production of sulphur hydroxide which is highly corrosive and explosive. 99% of the biocides that are added to the injection fluids remains in the bedrock reservoir, only 1% is extracted along with the produced fluids (CHARM default) and discharged overboard. The majority of these biocides remains in the bedrock reservoir which is sealed off when oil exploration ends. The fraction that remains in the bedrock reservoirs is not considered relevant for environmental risk assessment as it is locked in the earth's crust at a depth of several kilometres. As a worst-case approach the compound's hydrophobicity is not taken into account and therefore sorption to the oil phase is not included. The concentration in the produced water is calculated according to CHARM, which is subsequently applied to derive the daily emission from a single platform:

$$C_{pw} = \frac{f_r \cdot C_{inj} \cdot V_{inj}}{V_{pw}} \qquad (2$$

$$E_{local} = C_{pw} \cdot t \cdot \frac{V_{pw}}{24} \qquad (3$$

where:

–	C_{pw}	concentration in the produced water (mg/L)	O
–	f_r	fraction of biocide released to the open sea (0.01)	D
–	C_{inj}	the concentration of the active substance in the injection fluid according to the instructions of use (mg/L)	S
–	V_{inj}	volume of the water injected daily (17 000 m³/d)	D
–	V_{pw}	volume of the produced water (15 000 m³/d)	
–	E_{local}	daily emission from one platform to the open sea per platform (g/d)	O
–	t	duration of the treatment according to the instructions of use (t ≤ 24 hrs)	S

Closed drain systems

Produced water that is extracted from the bedrock reservoir is separated into water, oil and gas at the platform. Although these separation processes are effective, a small fraction remains that consist in both oil and water. This fraction is stored in the closed drain system and subsequently emptied in the produced water stream when completely filled (about 10 m^3). The biocides that are added to the closed drain systems are eventually discharged to the open sea along with the produced water. The closed drain systems are disinfected occasionally, for instance once a week. Because complete discharge occurs for a few hours once a week, emission to the environment is rather batchwise than continuous.

$$E_{local} = C_{closed\ drain} \cdot DOSE \cdot 10^{-3} \quad (4$$

where:

– E_{local}	daily emission from one platform to the open sea per platform (g/d)	O
– $C_{closed\ drain}$	the concentration of the active substance in the (diluted) product (mg/L)	S
– DOSE	amount of product applied for a single event (L)	S

Calculation of PEC_{marine}

Two PECs are calculated, namely the background concentration in the open sea and subsequently the concentrations in the vicinity of a single platform. The background concentration is calculated with MAMPEC for the ‘Default open sea’ scenario. This scenario assumes an open sea with a surface area of 200 km^2 in which 20 platforms are located (CHARM default = 0.1 platform/km^2), an average depth of 20 m, and a flow velocity of 1 m/s. In order to meet MAMPEC’s requirements, the daily emission from a single platform is transferred into a daily total load according to:

$$E_{MAMPEC} = \sum E_{local} \cdot n_{platform} \quad (5$$

where:

– E_{MAMPEC}	Total emission (input value for MAMPEC in g/d)	O
– ΣE_{local}	total daily emission from a single platform to the open sea (g/d)	O
– $n_{platform}$	number of platforms (20)	D

The results is subsequently entered in MAMPEC in the ‘Emission window’ behind ‘Total emission’ (uncheck ‘Use calculated values first). PEC_{marine} is subsequently calculated by using the compound’s physical-chemical properties. The recommended properties for the open sea are given below.

Length	20 km
Width	10 km
Depth	20 m
Latitude	50°N
Silt concentration	5 g/m³
Temperature	9°C
Salinity	34 psu
Particular organic carbon	0.3 mg/L
Dissolved organic carbon	0.2 mg/L
pH	8
Chlorophyll	3 µg/L
Tidal current (Flow velocity)	1 m/s

During or right after discharge, high concentrations may persist in a water body for a certain length of time until extensive mixing results in mean concentrations. Not taking exposure to peak concentrations within gradients into account could lead to an underestimation of risk, especially for rapidly degrading substances. Therefore, PEC_{marine} calculated with MAMPEC must be corrected for the peak concentration as recommended in the exposure scenario document for ballast water discharges:

$$PEC_{marine} = \frac{C_X + (S-1) \cdot C_{mean}}{S} \qquad (6$$

where:

– PEC_{marine}	predicted environmental concentration in seawater (mg/L)	O
– C_X	concentration of the active substance in the water that is discharged overboard where X is C_{inj}, $C_{closed\ drain}$ or C_{GBS} (mg/L)	S
– S	dilution factor for the receiving seawater (1000)	D
– C_{mean}	mean concentration in seawater derived from MAMPEC (mg/L)	S

References

- ESD PT 12, Harmonisation of Environmental Emission Scenarios for Slimicides. (product type 12). 2003;
- CHARM, Chemical Hazard Assessment and Risk Management; For the use and discharge of chemicals used offshore. User Guide Version 1.4 – 2004;
- Zipperle, A., J. van Gils, B. Van Hattum, S. Heise. Guidance for a harmonized Emission Scenario Document (ESD) on Ballast Water discharge. Umweltbundesamt (Federal Environmental Agency), Report No. FKZ 363 01 205, Dessau-Roßlau, Germany, 2011.

e-Consultation

Question 1: When the proposed method is applied, MAMPEC assumes that 20 platforms are lined up in a row (like ships in a shipping lane) and not equally distributed over 200 km². Therefore, the proposed approach may result in an overestimation of the actual PEC. Although it is unlikely that platforms are lined up, they are not equally distributed over the open sea, but often grouped. Is it therefore necessary to adjust the number of platforms? If yes, what number should be applied?

Answer DK: In Denmark we have 19 off-shore platforms. However there are only 13 discharge points. Therefore it is not the number of platforms that is important but the number of discharge points. The average water depth is around 40 m where the Danish platforms are situated.
In the Danish waters only few platforms are situated in an area of 20 km² radius. So maximum 5 platforms in a row is suggested.

Response NL: Only information was received from the Danish situation and therefore not able to conclude if DK's proposal is representative for all offshore oil field. We therefore suggest to apply 20 platforms being the worst-case. Note that the background concentration calculated with MAMPEC is usually low due to the open sea's volume and refreshment rate, and therefore its contribution to the PEC is negligible.

Question 2: The dilution factor of 50 is taken for the shipping lane scenario as proposed in the emission scenario document for ballast water discharge and based on a daily volume of 180000 m^3 contaminated ballast water. Although a single platform discharges 17000 m^3/d, resulting in 340000 m^3/d in the default open sea (20 × 10 km), only a fraction is contaminated with biocides as emission last only a few hours. Assuming that a complete discharge last 2 hours and the closed drain systems of all 20 platforms are emptied simultaneously, 28000 m^2 water is discharged at the same time. Considering that the total discharge is about six times lower, the dilution factor for oil platforms should be 300-350. Note that CHARM applies a dilution factor of 13000 for batchwise releases. Which dilution factor have to be applied?

Answer DK: The emission from the platforms situated in the Danish waters do not happen batch wise. It is a more continues emission; however there are variations from day to day.

Response NL: A daily discharge of 15 000 m^3 produced water may suggest a dilution factor of 1600 as the emission is 32 times lower than a single ballast water discharged. We suggest to apply a dilution factor of 1000 which is the highest acceptable dilution factor according to the TGD and also harmonised with CHARM. Note that due to SK's comments the emission is now/also calculated for continuous emission. No additional scenario for batchwise releases are therefore necessary.

<u>Question 3:</u> For continuous releases, however, the PEC is based on mean concentrations. The highest concentrations that are found in the vicinity of the platform are thereby ignored. There is in our opinion no difference between batchwise and continuous releases except that a time-weighed average approach may be justifiable for the first. Should the previously suggested approach for batchwise released be applied for continuous released as well? If yes, which dilution factor should be applied?

Response NL: Due to SE's comments the approach is slightly different and emission is based on continuous release representing the worst-case. In our opinion additional scenarios for batchwise release are not necessary.

<u>Question 4:</u> How to calculate $PEC_{sediment}$ for batchwise releases? The approach as described previously (formula 3) was applied as biocides are not mixed yet with seawater just after a discharge. However, sedimentation takes time. Is therefore $PEC_{sediment}$ calculated with MAMPEC sufficient to estimate the risks for sediment dwelling organisms?

Response NL: None of the member states responded on this question.

Comments SE:
SE's comments and NL's response are found in the document attached.