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Overview of hazardous substances potentially emitted from offshore industries to the marine environment

Part 2: Emissions from offshore oil and gas industry

by:

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On behalf of the German Environment Agency

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Abstract: Overview of hazardous substances potentially emitted from offshore industries to the marine environment

Within the RESOW project potential emissions of hazardous substances from the offshore industry into the North Sea and Baltic Sea are investigated. This report gives an overview on potential emissions of hazardous substances from the oil and gas industry, which are associated to the different activities on the offshore platforms. Emissions from drilling fluids, cuttings piles, accidental spills, produced water and corrosion protection materials are investigated. The individual substances are further investigated on their hazardous potential for the aquatic environment. Information from man-made chemicals was only available in a highly aggregated form and no information on individual substances could be retrieved from the aggregated data. Only for produced water information on individual substances could be obtained. The assessment criteria for the determination of hazardous potential is based on PBT criteria, H-phrase related to aquatic toxicity, SIN-list (Substitute It Now), OSPAR list of possible concern, OSPAR list of priority substances, the ECHA list of endocrine disruptive substances and the Water Framework Directive river basin specific pollutants and priority substances respectively listed in annex 6 and 8 of the German Ordinance on the Protection of Surface Waters, which represent the national implementation of the Water Framework Directive.

Kurzbeschreibung: Potentielle Schadstoffemissionen der Offshore Öl- und Gasindustrie in die Meeresumwelt

Im Rahmen des RESOW Projekts werden Einträge von gefährlichen Stoffen aus Offshore Industrie Quellen in die Meeresumwelt von Nord- und Ostsee untersucht. Dieser Bericht gibt einen Überblick über potentielle Emissionen von Schadstoffen aus der Offshore Öl- und Gasindustrie, die infolge der Arbeitsprozesse auf Offshore Plattformen zustande kommen können. Dabei werden Emissionen aus Bohrflüssigkeiten, Schneidölen, Produktionswasser sowie unfallbedingte Emissionen und Korrosionsschutzmaßnahmen untersucht. Die in den verschiedenen Eintragsquellen enthaltenen individuellen Substanzen werden weiterhin auf ihre Schadhaftigkeit für die Meeresumwelt analysiert. Da Informationen zu künstlich hergestellten Chemikalien nur in hoch aggregierter Form verfügbar waren und keine Informationen über individuelle Substanzen den aggregierten Daten entnommen werden konnten, war die Untersuchung künstlich hergestellter Chemikalien nicht möglich. Nur für Produktionswasser konnten individuelle Substanzen identifiziert werden. Die Bewertung des Gefährdungspotenzials basiert auf PBT-Kriterien (Persistenz, Bioakkumulation und Toxizität), Gefahrensätzen in Bezug auf aquatische Toxizität, der SIN-Liste (Substitute It Now), der OSPAR-Liste potentiell gefährlicher Stoffe, der OSPAR Liste von priorisierten Stoffen, der ECHA-Liste (European Chemical Agency) für endokrin wirksame Substanzen und den Wasserrahmenrichtlinien flussgebietsspezifischen Stoffen sowie prioritären Stoffen, welche in den Anhängen 6 und 8 der deutschen Oberflächengewässerverordnung gelistet sind, die eine nationale Implementierung der Wasserrahmenrichtlinie darstellt.

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List of abbreviations

BAT	Best Available Technique
BTEX	Benzene, Toluene, Ethlybenzene, Xylene
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CLP	Classification and Labelling of Chemicals
CP	Cathodic Protection
ECHA	European Chemical Agency
EOSCA	European Oilfield Speciality Chemicals Association
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HELCOM	Helsinki Commission
HMCS	Harmonised Mandatory Control System
HOCNF	Harmonised Offshore Chemical Notification Format
IO	Isomerized olefins
LAO	Linear Alpha Olefins
LCPA	List of Chemicals for Priority Action
MEG	Mono-Ethylene Glycol
NORM	Naturally Occurring Radioactive Materials
OBF	Oil Based Drilling Fluids
OCNS	Offshore Chemical Notification Scheme
OIC	Offshore Industry Committee
OPF	Organic-Phase Drilling Fluids
OSPAR	Oslo Paris Convention
PAH	Polycyclic Aromatic Hydrocarbons
PBT	Persistent, bioaccumulative and toxic
PEC	Predicted Environmental Concentrations
PNEC	Predicted No Effect Concentration
PLONOR	Pose Little Or No Risk
PRTR	Pollution Release and Transfer Register
PW	Produced Water
RBA	Risk Based Approach
REACH	Registration, Evaluation, Authorization and restriction of Chemicals
SBF	Synthetic Based Fluids
SIN	Substitute It Now

Summary

The RESOW project

The aim of the research project RESOW (Reduction of impacts of hazardous substances during installation and operation of offshore windfarms) is to give and overview on the emissions of hazardous substances from offshore industry. Thereby, the emissions of hazardous substances shall be analysed in relation to certain offshore structures and the lifecycles of the structures such as installation, operation and decommissioning. This report focuses on the oil and gas installations and their emissions to the marine environment.

Work package 2: focus on the oil and gas industry

In this project the focus is on the offshore oil and gas industry in the North Sea. The number of offshore oil and gas installations has been stable in the last decade, with the number of both oil and gas installations from 2009-2019 remaining quite constant during this period. In 2019 676 different installations with emissions and discharges were reported by OSPAR, consisting of 166 oil installations, 249 gas installations, 258 subsea installations and 3 other installations (OSPAR, 2021a). So far, 170 installations have been decommissioned and nine derogations have been granted. Over time the amount of oil which can be retrieved efficiently from wells will decrease, eventually resulting in an increasing number of offshore installations that will reach their end of life in the next two decades.

In this work package emissions of hazardous substances from the offshore oil and gas industry are investigated specifically. Therefore, emissions which are associated to the different sources on the offshore platforms, such drilling fluids, cuttings piles, accidental spills, produced water and corrosion protection materials are investigated. From these sources, produced water is the main source of discharges in the marine environment (OSPAR, 2020a). Produced water may contain high loads of heavy metals, phenols and aromatic hydrocarbons. Next to that, based on report from E-PRTR also emissions from corrosion protection can be a major source to the marine environment, especially the emissions of zinc, which can be similar in load to the emissions of zinc from produced water (E-PRTR, 2020). All other sources appeared to be minor compared to the emissions of produced water and corrosion protection, however due to a lack of information on individual substances in the discharges from other source from the oil and gas industry the composition and amount of substances emitted via other sources is mostly unknown.

Many of the identified substances emitted are expected to be hazardous to the marine environment

Most emissions originating from the offshore oil and gas sector are a mixture of both naturally occurring chemicals and man-made chemicals added to these materials to facilitate processes. Naturally occurring chemicals, such as hydrocarbons, end up in the environment via various oil and gas activities. The composition of the natural materials can be very variable and merely depends on environmental circumstances and the age of the well. The variability hampers a good quantification of these materials. Only for the natural composition of produced water enough information seems to be available for a good quantification. The composition of the man-made chemicals added to produced water and drilling fluids is hard to identify. On the one hand, recent studies by Parkerton et al. (2017) showed that man-made chemicals are negligible contributors to the overall risk in produced water, on the other hand De Vries & Jak (2018) identified that production chemicals could be a significant hazard for the marine environment. Information from man-made chemicals was only available in a highly aggregated form and no information on individual substances could be retrieved from the aggregated data. The risk

assessment of hazardous substances in this report is therefore merely based on the natural occurring materials present in produced water and on corrosion protection. The assessment criteria for the determination of hazardous potential is based on PBT criteria, H-phrase related to aquatic toxicity, SIN-list, OSPAR list of possible concern, OSPAR list of priority substances, the ECHA list of endocrine disruptive substances and the Water Framework Directive river basin specific pollutants and priority substances respectively listed in annex 6 and 8 of the German Ordinance on the Protection of Surface Waters, which represent the national implementation of the Water Framework Directive. Of the 32 analyzed substances 24 are identified as hazardous. Concluding, many of the substances emitted via produced water and corrosion protection are expected to be hazardous to the marine environment.

Zusammenfassung

Das Forschungsprojektes RESOW

Das Forschungsprojektes RESOW (Reduzierung von Schadstoffwirkungen bei Bau und Betrieb von Offshore-Windenergieanlage, Umspann- und Konverterplattformen und Seekabeln) soll einen Überblick über die Emissionen aus der Offshore Öl- und Gas sowie Windindustrie geben. Dabei sollen die potentiellen Emissionen von gefährlichen Stoffen aus den verursachenden Offshore-Aktivitäten und den assoziierten Lebensphasen der Struktur (Installation, Betrieb und Stilllegung/Rückbau) analysiert werden. Dieser Bericht greift das Arbeitspaket 2 des Forschungsprojektes auf, dass sich mit den potentiellen Emissionen aus der Öl- und Gasindustrie in die Meeresumwelt beschäftigt.

Arbeitspaket 2: Öl- und Gasindustrie

Dieses Projekt befasst sich mit der Offshore-Öl- und -Gasindustrie in der Nordsee. In diesem Zeitraum von 2009-2019 blieb die Anzahl der Öl- und Gasanlagen Offshore relativ konstant. Im Jahr 2019 wurden etwa 676 verschiedene Installationen mit Emissionen bei OSPAR gelistet. Darunter befanden sich 166 Öl Installationen, 249 Gas Installationen, 258 Installationen unter Wasser und 3 weitere Installationen (OSPAR, 2021a). Bislang wurden 170 Offshore Anlagen der Öl- und Gasindustrie rückgebaut und 9 Ausnahmeregelungen erteilt. Da mit zunehmender Dauer der Ölgewinnung in einem Gebiet die Menge an Öl, die effizient aus den Bohrlöchern gefördert werden kann, abnimmt, werden in den nächsten zwei Jahrzenten eine steigende Anzahl von Offshore-Anlagen ihr Lebensende erreichen.

In diesem Bericht werden die Emissionen von gefährlichen Stoffen aus der Offshore Öl- und Gasindustrie untersucht. Dafür werden die Stoffe untersucht, die mit den verschiedenen Quellen auf den Offshore Plattformen in Verbindung gebracht werden können wie z. B. Bohrfluiden, Schneidöle, unfallbedingter Austritte, Produktionswasser und Korrosionsschutzmaßnahmen. Das Produktionswasser stellt bei weitem die maßgeblichste Quelle für den Eintritt von gefährlichen Stoffen in die Meeresumwelt dar (OSPAR, 2020a). Produktionswasser kann hohe Mengen von Schwermetallen, Phenolen und aromatische Kohlenwasserstoffe enthalten. Weiterhin sind auch Stoffemissionen aus dem Korrosionsschutz eine wichtige Emissionsquelle, insbesondere die Emission von Zink. Dabei kann die Emissionsmenge von Zink infolge von Korrosionsschutzmaßnahmen der Emissionsmenge von Zink aus dem Produktionswassers entsprechen (E-PRTP, n.d.). Im Vergleich zu den Emissionen aus Produktionswasser und Korrosionsschutz sind die Anteile der anderen Quellen eher als gering zu beurteilen. Jedoch sind die individuellen Stoffe, Zusammensetzung und Menge der Abflüsse infolge weiterer Quellen aus der Offshore Öl- und Gasindustrie meistens unbekannt.

Viele der identifizierten Stoffe sind als gefährlich für die marine Umwelt einzuordnen

Die meisten Emissionen aus dem Öl- und Gassektor stellen eine Mischung aus natürlich vorkommenden Chemikalien und künstlichen Chemikalien dar, die in verschiedenen Prozessen zum Einsatz kommen. Natürlich vorkommende Chemikalien, wie Kohlenwasserstoffe und Feststoffe, gelangen durch verschiedene Öl- und Gasaktivitäten in die Umwelt. Die Zusammensetzung der natürlichen Materialien kann sehr variabel sein und hängt von den Umweltbedingungen und dem Alter des Bohrlochs ab. Die Variabilität erschwert eine gute Quantifizierung dieser Stoffe. Nur für die natürliche Zusammensetzung des Produktionswassers sind genügend Informationen für eine gute Quantifizierung vorhanden. Die Zusammensetzung der künstlich hergestellten Chemikalien, die dem Produktionswasser und den Schneidölen zugesetzt werden, ist schwer zu ermitteln. Auf der einen Seite haben jedoch neuere Studien gezeigt, dass die künstlich hergestellten Chemikalien einen vernachlässigbaren Beitrag zum

Gesamtrisiko leisten (Parkerton et al., 2017). Auf der anderen Seite, zeigen andere Studien das künstlich hergestellte Chemikalien sehr wohl eine beträchtliche Gefahr für die marine Umwelt darstellen(De Vries & Jak, 2018). Informationen zu künstlich hergestellten Chemikalien sind ausschließlich in hoch aggregierter Form verfügbar und keine Informationen zu individuellen Stoffen kann von diesen Informationen entnommen werden. Aus diesem Grund konzentriert sich die Risikobewertung von Gefahrstoffen in diesem Bericht auf die natürlich vorkommenden Stoffe, die im Produktionswasser vorhanden sind. Die Bewertung des Gefährdungspotenzials basiert auf PBT-Kriterien (Persistenz, Bioakkumulation und Toxizität), Gefahrensätzen in Bezug auf aquatische Toxizität, der SIN-Liste (Substitute It Now), der OSPAR-Liste potentiell gefährlicher Stoffe, der OPSAR Liste von priorisierten Stoffen, der ECHA-Liste (European Chemical Agency) für endokrin wirksame Substanzen und den Wasserrahmenrichtlinien flussgebietsspezifischen Stoffen sowie prioritären Stoffen, welche in den Anhängen 6 und 8 der deutschen Oberflächengewässerverordnung aufgeführt sind, die eine nationale Implementierung der Wasserrahmenrichtlinie darstellt. Von 32 untersuchten Stoffen wurden 24 als gefährlich eingestuft. Daher sind Stoffe, die aus Produktionswasser und Korrosionsschutzmaßnahmen emittiert werden, als gefährlich für die marine Umwelt einzuschätzen.

1 Introduction

1.1 Goal of the project

The overall goal of the RESOW project is to create an overview of the most relevant hazardous substances, emitted from offshore sources to the marine environment, because of activities specific related to offshore wind farming (work package 1), as a result of offshore oil and gas exploration and production (work package 2), and their relation with emissions resulting from other offshore activities like maritime transport and aquaculture (work package 4). Eventually in work package 3, recommendations are proposed to reduce emission from offshore wind farming, using Best Available Technology (BAT). In this report the results of Work Package 2 are described.

The goal of Work Package 2 is to compile the possible emissions of pollutants from offshore oil and gas installations during construction, operation and decommissioning as comprehensively as possible. This includes a description of the usual practice (which substances are usually used in the installations mentioned) and estimates of the quantity of the pollutants used that are released into the marine environment. In Work Package 1 a list of potential hazardous substances from the offshore wind is compiled. In Work Package 2 a list of potential hazardous substances from the offshore oil and gas industry has been compiled, which is presented in this report.

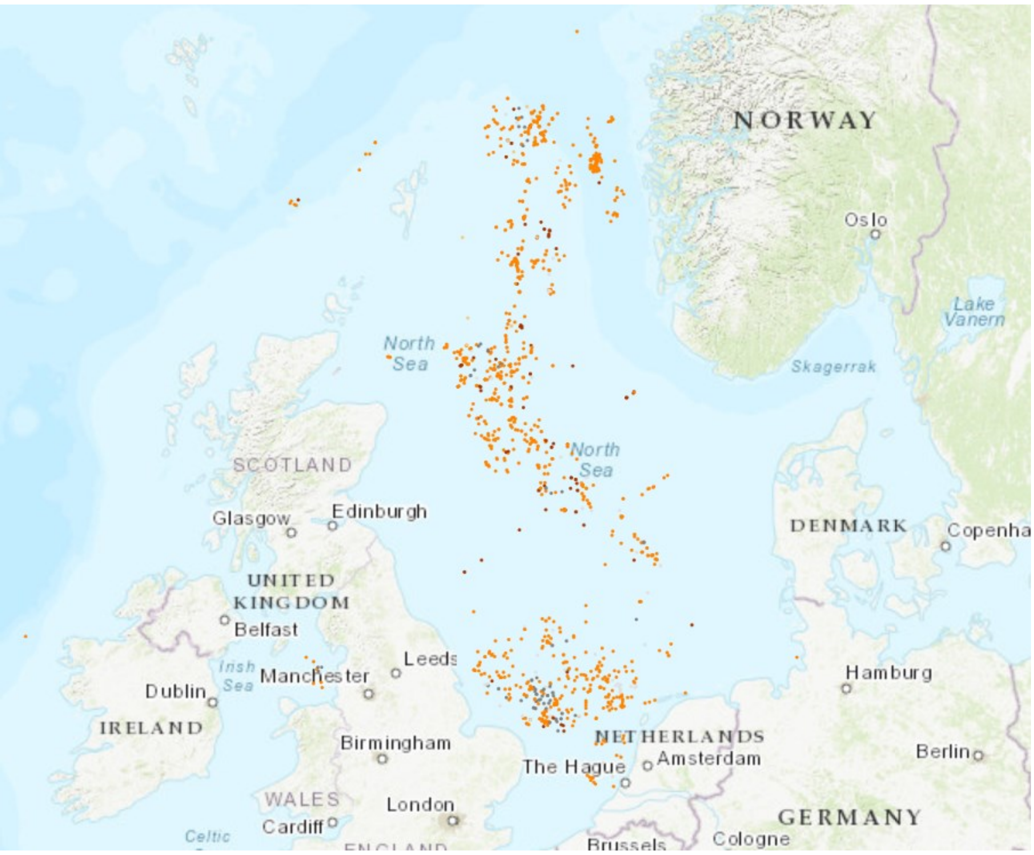
In March 2021 an expert meeting was held to evaluate and discuss the results of the WP2 report with experts from UBA (Umweltbundesamt, German Environmental Agency), BSH (Bundesamt für Seeschifffahrt und Hydrographie, Federal Maritime and Hydrographic Agency), Danish Environmental Protection Agency (EPA), OSPAR, EOSCA (European Oilfield Speciality Chemicals Association) and LBEG (State Office for Mining, Energy and Geology) and Deltares.

The regional scope differs between WP1 and WP2. For emissions from the oil and gas industry (WP2), all installations in the OSPAR region are considered, whereas for the offshore wind industry, the focus of the analysis is on the German part of the North Sea and Baltic Sea.

Figure 1 displays a map with the locations of the offshore oil and gas installations in 2019, the most recent year available. In Figure 2 the number of different installations with emissions and discharges covered by OSPAR measures during the time period 2009-2018 is presented. From this figure it becomes clear that the number of both oil and gas installations has remained quite constant during this period. Data from 2019 shows a similar trend to the years 2009-2018, with a total of 166 oil installations, 249 gas installations, 258 subsea installations and 3 other installations (OSPAR, 2021a). Subsea installations can range in complexity from a single satellite well with a flowline linked to a fixed platform or an onshore installation, to several wells on a template or clustered around a manifold, and transferring to a fixed or floating facility, or directly to an onshore installation. Subsea production systems can be used to develop reservoirs, or parts of reservoirs, which require drilling of the wells from more than one location. They are all linked and subsea systems in reality often have hydraulic leaks. In this report the focus is on the oil and gas installations, as these cause emissions into the marine environment.

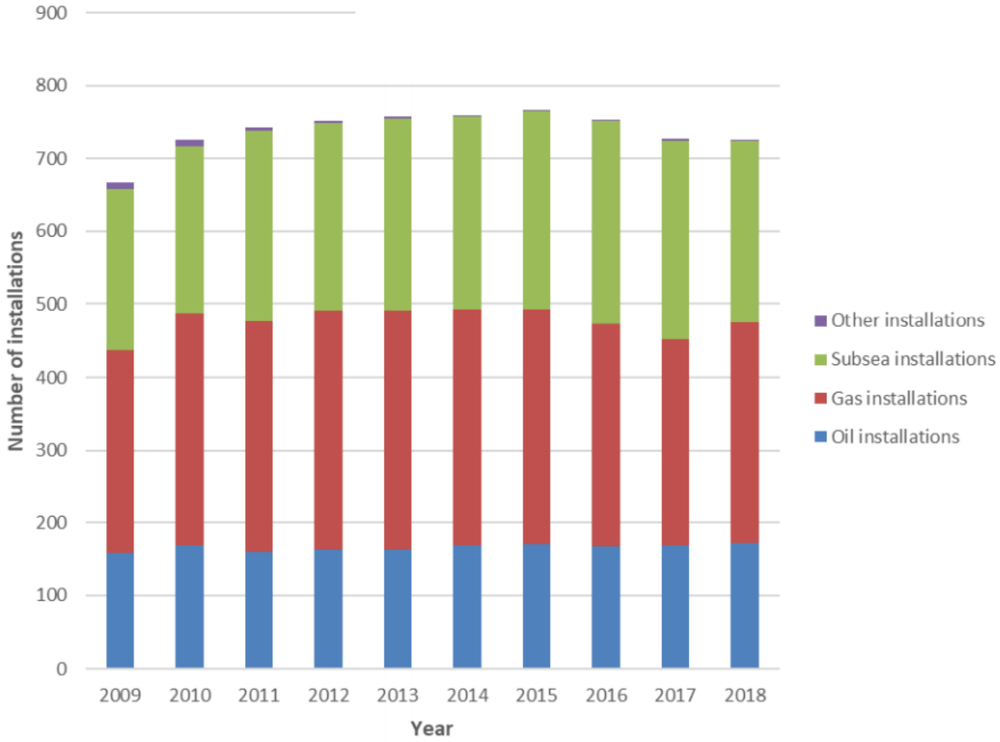
Every two years the offshore installations inventory is updated by OSPAR Contracting Parties to include any changes and review any possible errors detected. In 2021 the inventory of the offshore installations inventory 2019 has been published. So far, 170 installations have been decommissioned, 105 installations are currently being dismantled and nine derogations have been granted (OSPAR, 2021b). A derogation permit can be granted in order to leave certain parts of offshore installations in place as stated in OSPAR Decision 98/3 (OSPAR, 1998). This information is available on the website of OSPAR for the period from 2001-2019 (with a 2-year interval) and can be downloaded under Data Sources and Related Files (OSPAR, 2021b). Over time the amount of oil which can be retrieved efficiently from wells will decrease, as the oil reservoirs decline, eventually resulting in an increasing number of offshore installations that will reach their end of life in the next two decades (OSPAR, n.d. a).

Figure 1: Map showing the locations of offshore installations in the OSPAR region in 2017. Orange = operational, red = decommissioned, grey is closed, yellow = under construction.



Source: https://odims.ospar.org/en/submissions/ospar_offshore_installations_2019_01/ (OSPAR, 2021b)

Figure 2: Number of installations in the OSPAR region during the period 2009-2018.



Source: https://www.ospar.org/documents?v=43787 (OSPAR, 2020a)

In Chapter 2 the approach for reaching a list with potential hazardous substances originating from the offshore oil and gas industry will be described. In Chapter 3 the main discharges from the offshore oil and gas industry are described and in Chapter 4 the results of the assessment of the substances in the identified discharges are described. Chapter 5 summarizes the conclusions.

2 Emissions from the offshore oil and gas sector

2.1 Introduction

2.1.1 Exploration, production and decommissioning

Emissions from the offshore oil and gas sector can be divided in emissions in the exploration phase, development & construction phase, production phase and decommissioning phase. Depending on the phase, different emission routes can be important. In general, the same activities and consequently same type of emissions occur for both oil and gas production, but the intensity of emissions varies due to the operations being conducted.

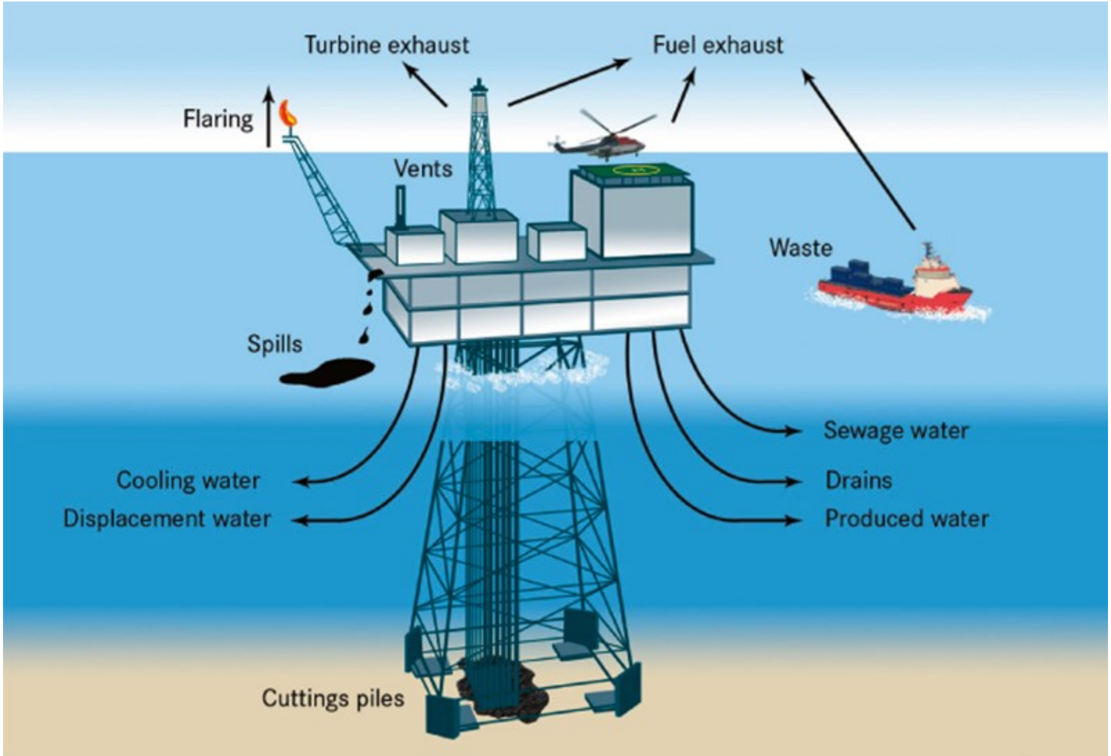
During the **exploration phase**, the search for deposits of oil and natural gas in the earth, drilling is one of the major activities. In this phase, the emissions from drilling fluids will be the most relevant. Oil output from the North Sea has dropped since the turn of the century as fields have got older. Some OSPAR contracting parties are considering a ban on new oil exploration licenses in the North Sea from 2040 on, as a move away from fossil fuels. However, some drilling fluids may still be emitted from the offshore oil and gas industry, as for example exploration still takes place in the OSPAR region.

Once the exploration phase is over and drilling locations have been selected developmental drilling can start. During the **development & construction phase** one or more wells will be drilled and constructed, such as production wells. As such, production begins when development wells are drilled and completed.

Figure 3 displays a schematic overview of the potential emissions originating from the offshore oil and gas industry during the **production phase** of oil or natural gas.

In terms of time and volume, this is regarded as the most important phase for emissions from the oil and gas industry, and most of the contents of this report is dedicated to this phase.

Figure 3: Overview of emission routes of the offshore oil and gas industry ©OSPAR Commission



Source: https://www.ospar.org/work-areas/oic/discharges (OSPAR, n.d. c)

During the **decommissioning phase** the disposal of disused offshore installations takes place. The assessment of the disposal options should also consider the impacts on the marine environment, including exposure of biota to contaminants associated with the installation (OSPAR, 1998). Within this respect, the potential removal of structures and cutting piles, consisting of solid material on the seabed arising from drilled rock, could be a major source of emissions of hazardous substances. According to OSPAR decision 98/3 on the Disposal of Disused Installations reuse, recycling or final disposal on land will be the preferred option for the decommissioning of offshore installations in the maritime area (OSPAR, 1998). In certain situations, a derogation permit can be granted to leave certain parts of offshore installations in place as stated in OSPAR Decision 98/3 (OSPAR, 1998). The situations in which derogation permits may be granted include, amongst others, gravity based concrete installations, floating concrete installations and steel installations weighing more than ten thousand tonnes in air (OSPAR, 1998). Therefore stakeholders (operators, national authorities) together should in this phase assess if the recommended option is to leave for instance cutting piles in place to degrade naturally alongside the footings of the steel jacket, thereby leaving a potential source of emissions of hazardous substances, such as polychlorinated biphenyls (PCBs) and heavy metals, on the seabed, or to remove and/or disturb the cutting piles, and treat them onshore if larger quantities need to be disturbed, thereby causing potential acute emission from hazardous substances, stored in the cutting piles or by re-suspending sediments, while removing (Tornero & Hanke, 2016).

2.1.2 Regulation and data collection regarding offshore oil and gas industry by OSPAR and EU

In contrast to WP1, more information is available for a number of emissions, originating from reporting programmes under regulations which are in place, and targeted monitoring programs which have been carried out by national authorities.

Especially relevant for the North Sea Region, the Offshore Industry Committee (OIC) in OSPAR collects and assesses data on the number of installations, the use and discharge of drilling fluids and cuttings, discharges of oil in produced water, chemicals used and discharged offshore, accidental spills of oil and chemicals and emissions to air. These data are compiled per Contracting Party and published annual OSPAR reports, for which the most recent is now available for the year 2018 (OSPAR, 2020a). For this, every contracting party delivers regularly a national assessment report to OIC. Also, the German assessment report can be found on the OSPAR website (OSPAR, 2019b). These reports only report aggregated data, and do not provide information concerning individual substances, especially not for the man-made chemicals, which means that they are of limited use for this report.

Because many offshore chemicals are harmful to the environment their use is strictly regulated based on their persistence, bioaccumulation, toxicity (PBT) properties. For man-made offshore chemicals, individual chemical suppliers must provide the national permitting authorities with data and information about chemicals to be used and discharged offshore in accordance with the OSPAR Recommendation 2010/03 on the Harmonised Offshore Chemical Notification Format (HOCNF)(OSPAR, 2010). This HOCNF format is put in to place to stimulate the offshore petroleum industry to replace environmentally hazardous offshore chemicals with less hazardous alternatives. The HOCNF demands that certain data regarding ecotoxicological properties must be available for each substance, including data on:

- Persistency/biodegradability
- Bioaccumulation/bioconcentration potential
- Aquatic toxicity

Under the terms of the current OSPAR Recommendation 2017/1 on Pre-screening scheme (OSPAR, 2017a), suppliers are required to ensure that substances used in offshore chemicals meet the relevant pre-registration or registration requirements of the REACH Regulation. Suppliers are therefore advised to follow the REACH compliance flowchart shown in Figure 1 of the OSPAR Guidelines for Completing the HOCNF before specific toxicity, biodegradation and bioaccumulation tests are commissioned and data is added on the HOCNF form. Next to this REACH legislation, operators also have to comply with other European legislation, like the EC regulation 528/2012 concerning the market and use of biocidal products (European Commission, 2012), and the EC regulation 1272/2008 on the classification, labelling and packaging of substances and mixtures (European Commission, 2008).

Since 2001 the use and discharge of chemicals used in the offshore oil and gas industry has been regulated by OSPAR. OSPAR uses two lists of substances, which are also relevant for the offshore oil and gas industry. The OSPAR List of Substances/Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR) contains substances whose use and discharge offshore are subject to expert judgement by the competent national authorities or do not need to be strongly regulated (OSPAR, 2021c). The PLONOR list takes into account bioaccumulation and biodegradability, please see OSPAR List of Substances Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (PLONOR) – Update 2021 for more information (OSPAR, 2021c). However, some substances on the PLONOR list are regarded as hazardous in dedicated German legislation (AwsV, 2017). Next to that, OSPAR operates a List of Chemicals for Priority Action (LCPA), a list of hazardous substances (OSPAR, n.d. d). OSPAR is undertaking a full review of the OSPAR List of Chemicals for Priority Action, to filter and rationalise it in light of the registration, evaluation and authorisation of chemicals (REACH) Regulation and on the prioritisation of substances under the Water Framework Directive. A new List is expected to be published in 2021/22.

According to OSPAR (2021d): 'To reduce the overall impact of offshore chemicals on the marine environment, OSPAR has adopted a Harmonised Mandatory Control System (HMCS) (OSPAR, 2000a) for use and reduction of discharges of offshore chemicals by the offshore oil and gas industry. This system promotes the shift towards the use of less hazardous or preferably non-hazardous substances. There is a common OSPAR interpretation of which chemicals are covered by the control system. OSPAR is working towards harmonising, where possible, the OSPAR HMCS approach with EC regulation 528/2012 concerning the market and use of biocidal products (European Commission, 2012).' Next to that, recommendations are in place to reduce the impacts of pollution by oil and/or other substances from cuttings piles (OSPAR, 2006a) and to manage the use of Organic-Phase Drilling Fluids (OPF) and the discharge of OPF-Contaminated Cuttings (OSPAR, 2000b). This latter recommendation aims to prevent and eliminate pollution by the use and discharge of OPF and OPF contaminated cuttings and by prohibiting the discharge of cuttings contaminated with OBF at a concentration greater than 1% by weight on dry cuttings and by other measures. The progress on these recommendations is reported in the annual reports of OSPAR Offshore Industry Committee (OIC); see the report on Discharges, Spills and Emissions from Offshore Oil and Gas Installations 2018) (OSPAR, 2020a).

Since 2001 the use and discharge of chemicals have been covered by several OSPAR measures. OSPAR uses the term "substitution chemical" for chemicals which are or contain substances that are candidates for substitution, according to OSPAR Recommendation 2006/3 (OSPAR, 2006b). This includes chemicals or substances which are:

- on the OSPAR LCPA;
- inorganic with LC50 or EC50 less than 1 mg/l;
- have biodegradation of less than 20%;
- meets two of the following three criteria:
  - biodegradation less than 60%;
  - BCF larger than 100 or Log Pow ≥ 3;
  - LC50/EC50 less than 10mg/L.

Chemicals that are considered to 'Pose Little or No Risk' to the environment are referred to as PLONOR chemicals (OSPAR, 2021c). Chemicals that are neither PLONOR nor candidates for substitution include those that are:

- Inorganic with LC50 or EC50 greater than 1 mg/l,

- Ranking chemicals, these chemicals are ranked according to OSPAR Recommendation 2000/2 Appendix 1 III (OSPAR, 2000a) and are all those chemicals that do not fall into one of the abovementioned categories. Ranking is done according to generic PEC/PNEC ratios in order to have an indication of the relative risk (OSPAR, 2000a). The PEC/PNEC ratio is the ratio between the Predicted Environmental Concentration (PEC), which is the predicted concentration of a chemical in the environment, and the Predicted No Effect Concentration (PNEC), which is the predicted concentration of a chemical below which adverse effects will most likely not occur. The ranking facilitates management decisions which can lead to the following outcomes:

  A. Permission of offshore chemicals for use or discharge;
  B. Substitution of offshore chemicals for use or discharge;
  C. Temporary permissions of offshore chemicals for use or discharge;
  D. Refusal of permission of offshore chemicals for use or discharge.

Next to OSPAR, the European Commission also has a Directive in place to control and reduce the impact of industrial emissions on the environment, namely the Industrial Emissions Directive

(Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)) (EU-Directive 2010/75/EU). The plan to lower emissions is based on Best Available Technology (BAT) to help reach the goals of the directive. The plan allows for flexibility given the best available technology; exemptions to the directive can be granted to firms as well if the cost is greater than the benefit (European Commission, n.d.). In this context, a guidance document on BAT for upstream hydrocarbon exploration and production has been drafted (European Commission, 2019). This guidance document merely refers to the activities performed in OSPAR. The development of a BAT reference document (BREF) could help to anchor the BAT idea more firmly in the offshore oil and gas industry.

2.1.3 Regulation and data collection regarding offshore oil and gas industry by national authorities

Based on the information sent by the chemical supplier the national authority carries out the pre-screening of offshore chemicals according to OSPAR Recommendation 2017/01 (OSPAR, 2017a) and takes the appropriate regulatory action, such as issuing discharge permits. An aggregated list of chemicals only presented per category is presented per Contracting Party in the annual reports of OSPAR.

Germany, as a very small oil and gas producer, does not have a registration system for offshore chemicals itself as the effort would be disproportionate (OSPAR, 2019). As nearly 100 % of the activities in the German Continental Shelf are directed from operators and contractors in the Netherlands, the German system of handling chemicals is based on the Dutch (and UK) system, called Offshore Chemical Notification Scheme (OCNS).

In the **United Kingdom** chemicals are registered by the Centre of Environment, Fisheries and Aquaculture Science (CEFAS Laboratories) in the UK. Every supplier is obliged to register their chemicals at CEFAS. After an analysis of the dossier each mixture of chemical receives a risk ranking so that the use and discharge is controlled. More information about this system can be found on the CEFAS website (CEFAS, n.d.). A link towards a list of approved chemicals can also be found there (CEFAS, 2021). Presence on the list does not necessarily mean that the product is used. Only national permitting authorities have this information per operator available, which hampers the creation an overall overview of the use of these chemicals.

In the **Netherlands**, the discharge permit has to comply with the Mining Act (NLOG Dutch Oil Portal (n.d.). According to this legislation, operators have to report annually the use of man-made offshore chemicals. The Netherlands are applying the CEFAS system, as described in two protocols. In part 1 the procedures that are common to both UK and Netherlands registrations are documented (CEFAS, 2020a), whilst in Part 2 procedures that are specific to the Netherlands are described (CEFAS, 2020b).

The **Norwegian** legislation and regulation on offshore chemicals expands beyond the HOCNF and REACH demands, and details about this regulation is provided by the Norwegian “Activities Regulation”. Briefly, the Activities Regulation requires that operators are responsible for the environmental evaluation/ranking of the offshore chemicals that they are using, and for choosing the chemicals that give the lowest risk of environmental harm). By making operators responsible Norway ensures that they follow the requirements. More information can be found on the website of the Norwegian Petroleum Safety Authority (Petroleum Safety Authority Norway, 2020).

2.1.4 Number of oil and gas installations in the OSPAR and HELCOM area

Table 1 provides an overview of the installations in the OSPAR area with discharges to the sea. At the moment Germany has only two producing installations and is a small producer of oil and gas in the OSPAR region. One of the two installations operate in a zero-discharge mode to sea, i.e. there are no discharges to the marine environment. In 2019, the 30 mg/l performance standard for oil in produced water, undertaken in accordance with OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations, was not exceeded by Germany (OSPAR, 2021a). Additionally, no spills to sea from the oil and gas industry occurred during the reporting period in the German Continental Shelf. Germany operates no offshore installations in the Baltic sea. Only small oil and natural gas fields are explored in the Baltic Sea, mostly for the Polish coast (Oilprice.com, 2017).

In the following sections the most relevant emissions originating from offshore oil and gas installations will be discussed.

Table 1: Total number of installations in the OSPAR maritime area with discharges to the sea, including subsea and other installations in the period from 2009-2019* (OSPAR, n.d. b).

Country	2009	2010	20113	2012	2013	2014	2015	2016	2017	2018	2019
Denmark	20	20	18	15	14	20	20	20	21	21	21
Germany	3	2	2	2	2	2	2	2	2	2	2
Ireland	1	2	2	2	2	2	2	3	3	2	7
Netherlands	135	138	128	127	127	127	127	107	107	154	101
Norway	143	136	103	115	114	114	115	116	117	81	82
Spain	2	2	2	1	2	2	NI	NI	NI	NI	2
UK	439	484	487	489	496	495	500	505	477	466	461
Total	**743**	**784**	**742**	**751**	**757**	**762**	**766**	**753**	**727**	**726**	**676**

*Adapted from the yearly OSPAR reports on Discharges, Spills and Emissions from Offshore Oil and Gas Installations from 2009-2019, available via https://odims.ospar.org/en/search/?datastream=discharges_oil_and_gas (OSPAR, n.d. b).

3 Discharges: types, quantities, hazardous substances

3.1 Miscellaneous discharges

A number of relatively small discharges with low environmental impact originating from offshore oil and gas installations can be distinguished by amongst others:

- Open drains collate rainwater, minor spils etc. and are sent to a caisson system where the oils are collected from the top of the water column and returned for processing. They do not usually discharge straight to sea.
- Closed drains are linked to production vessels/equipment so that hazardous fluids are directed away in a controlled manner.
- Bilge water is a specific issue in floating systems and it is not found in fixed platforms. The contaminated water collected in engine rooms and machinery spaces. This can contain some small amount of fuel oil or lube oil, some dust, some rust.
- Displacement water is the seawater which is used for ballasting the storage tanks of the offshore installations. When oil is loaded into the tanks, the water is displaced, and is discharged. This water may contain small amounts of oil. Most conventional oil and gas platforms do not use displacement water.
- Cooling water is natural seawater used to cool different closed systems on the platforms. Biocides as Sodium Hypochlorite may be added to cooling water to prevent growth of organism in the systems. During this process, a wide uncontrolled range of chloride containing substances may be formed, from which some may have potential PBT properties (Van Hattum et al., 2004). As the amount of chloride is minimized as much as possible, the emitted amounts are considered not significant compared to other sources.
- Gas dehydration is the process of removing water from the natural gas stream. Various substances can be used for this purpose, such as triethylene glycol (TEG) or ethylene glycol (MEG). The resulting water flow generally contains high concentrations of aromatics.
- Sewage water originates from the facilities on the installation to accommodate their workforce, and will mainly contain nutrient emissions, caused by human activities.
- Incidental releases from firefighting systems, flare systems (only if fluorine-free firefighting foams are used and/or fire water retaining basins are present).

Often the different streams of drain, bilge water and sewage water are treated on the platform before discharge, thereby already reducing the environmental impact. According to Bakke et al. (2013), the total amount of contaminants discharged via displacement water and drain water is relatively low compared to drilling fluids and produced water. In another study, the output of a modeling exercise combined with the results of a number of bioassays performed on a number of selected effluents on an oil installation indicated that discharge of these effluents (a.o. drainage water and cooling water) did not result in concentrations, or duration of exposure, that would elicit toxic effects to organisms living in the surrounding environment (Hughes et al., 2019). Also, a recent report of Oil and gas UK states that the emissions mentioned above are very small (Oil and Gas UK, 2018).

3.2 Drilling fluids

Next to produced water, drilling fluids are a potential source of contaminants during exploration. Drilling fluids are sometimes also called drilling muds. Drilling fluids are used to aid the drilling of boreholes into the earth, while drilling oil and natural gas wells. The function of drilling fluids is to lubricate and cool the drill bit, stabilize the borehole, control pressure, and bring cuttings to the installation. To do so, a drilling-fluid system comprises a volume of fluid that is pumped with specially designed mud pumps from the surface pits, through the drill string exiting at the bit, up the annular space in the wellbore, and back to the surface for solids removal and maintenance treatments as needed. Drilling waste also comprises used drill mud that has lost its technical properties. Until the mid-1990s the discharge of cuttings with oil-based drilling fluids (OBF) was the main source of oil hydrocarbons entering the marine environment from the offshore petroleum industry. The OSPAR decision 2000/3 on the use of Organic-Phase Drilling Fluids (OPF) (OSPAR, 2000b) and the discharge of OPF-Contaminated Cuttings prohibited the discharge of cuttings contaminated with OPF at a concentration greater than 1% by weight on dry cuttings and by other measures. Because of this decision the use OBF was gradually eliminated by regulation within the OSPAR region (OSPAR, 2000b), making produced water now the major source.

The major components of drill muds are a liquid (water, oil, or another organic fluid) and a weighting material containing substances including barite ($BaSO_4$) and ilmenite ($FeTiO_3$), both of which contain traces of heavy metals such as lead. Various additives are used to improve the technical performance of the mud. Among these are viscosifiers (e.g. polyacrylates and other organic polymers), emulsifiers (e.g. alkyl acrylate sulphonate and polyethylene oxide), pH and shale control agents, and deflocculants. The additives vary between drilling operations and in the course of the drilling. The chemicals used as additives in the drill muds today are mostly classified as PLONOR (Pose Little or No Risk to the Environment) by the OSPAR Commission (Bakke et al., 2013).

Nowadays most drilling operations are designed to minimise spills – cuttings are generally not allowed to be discharged to sea even if WBF – with 'Skip and Ship' operations being standard practice where cuttings are returned to shore by skip during drilling operations.

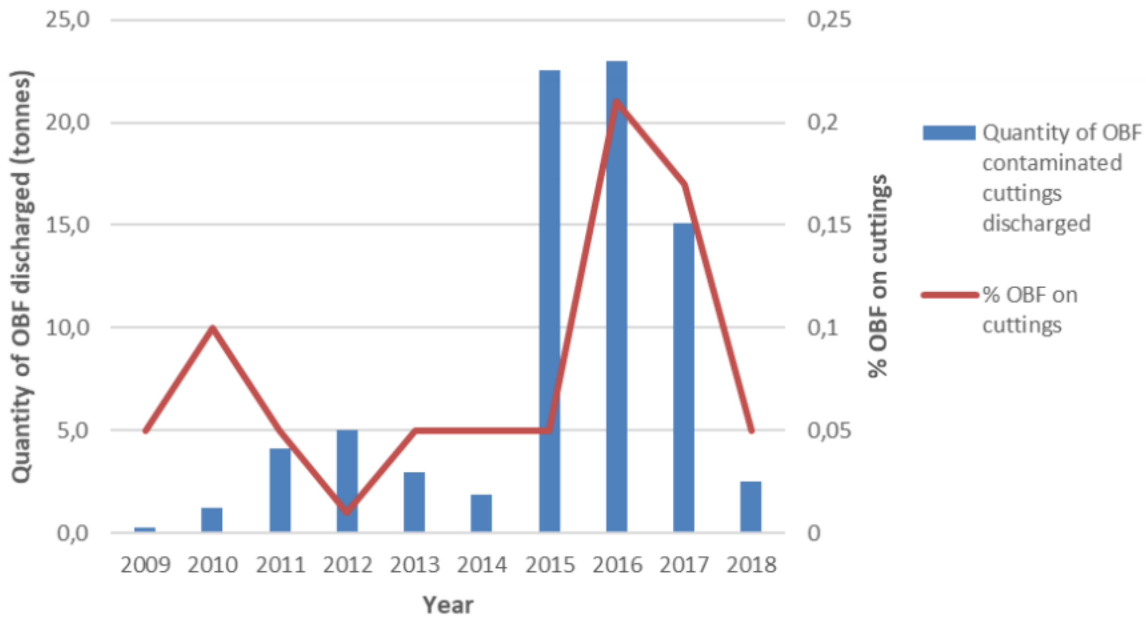
Drilling fluids are classified according to their base:

- **Water Based fluids (WBF)**. Solid particles are suspended in water or brine. Oil may be emulsified in the water, in which case water is termed the continuous phase. In water base muds the solids consist of clays and organic colloids added to provide the necessary viscous and filtration properties, heavy minerals (usually barite, added to increase the density when needed), and solids from the formation that become dispersed in the mud in the course of drilling. The water contains dissolved salts, either derived from contamination with formation water or added for various purposes. Clays as they occur in nature are composed of various clay minerals, such as montmorillonite, illite, and kaolinite, of which montmorillonite is by far the most active. Other minerals, such as quartz, feldspar, calcite, etc., may also be present, in both the colloidal and silt-size ranges. Some commercial bentonite or attapulgite also may be added to aid in fluid-loss control and to enhance hole-cleaning effectiveness. Water-based fluids are used to drill approximately 80% of all wells. In practice, current UK and Norwegian legislation allows only WBF cuttings and used WBF to be discharged offshore. Bakke et al., (2013) concluded that it is obvious that discharged WBF cuttings cause biological effects both during suspension in the water masses and after sedimentation. The studies indicate that the effect mechanism is mainly physical stress, but chemical toxicity cannot be ruled out. This statement was confirmed by the relatively high

PNEC values of 7.6 mg/L and 17.9 mg/L respectively for suspended bentonite and barite clays, the main constituents of WBF, calculated by Smit et al. (2008), which was much higher than the chronic PNEC value for suspended cuttings of 0.8 mg/L, as calculated by Bechman et al. (2006). Older studies stated that discharges of WBFs and the associated cuttings have little or no adverse, long-term biological impact in the water column or on the seafloor (Hinwood et al, 1994). According to most notifications provided by companies to ECHA in CLP notifications no hazards have been classified for barite. According to the same classification by ECHA bentonite causes serious eye irritation, causes skin irritation and may cause respiratory irritation. Both bentonite and barite are listed on the OSPAR PLONOR list (OSPAR, 2021c).

- **Oil Based fluids (OBF).** Oil-based fluids in use today are formulated with diesel, mineral oil, or low-toxicity linear olefins and paraffins. Diesel and mineral oils are refined from crude oil and may contain mixtures of aromatic hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). Due to concerns regarding toxicity and persistency the use of oil-based fluids formulated with diesel and mineral oil almost ceased. By refining the distillation process of crude oil the amount of (poly)aromatic hydrocarbons (PAHs) could be reduced which results in a lower toxicity (International Association of Oil & Gas Producers, 2016). Olefins and paraffins are often referred to as "synthetics" although some are derived from distillation of crude oil and some are chemically synthesised from smaller molecules. Barite is used to increase system density, and specially-treated organophilic bentonite is the primary viscosifier in most oil-based systems. Most conventional oil-based fluids are formulated with calcium chloride brine as shale inhibitor. Studies, mostly performed in the North Sea, show that discharge of OBF cuttings may cause persistent adverse biological effects at the seafloor within at least 1 km of the platform (Kingston 1992; Olsgard and Gray, 1995; Ellis et al, 2012). New thermal desorption treatment technologies enable the achievement of a concentration of OBF of just less than 1% by weight on dry cuttings. As there has been an increase in the use of these techniques there has been an increase in the discharge of thermally treated OBF, however, all discharges have been significantly lower than the standard of 1% OPF fluid by weight on dry cuttings (OSPAR, 2020a), see also Figure 4.

Figure 4: Quantity of oil based fluids (OBF) cuttings (left y-axis) and the 1% organic phase fluid by weight on dry cuttings (right y-axis) in the OSPAR region discharged between 2009-2018.



Source: https://www.ospar.org/documents?v=43787? (OSPAR, 2020a)

- **Synthetic-based fluids (SBF)** were developed to reduce the environmental impact of offshore drilling operations, but without sacrificing the cost-effectiveness of oil-based systems. SBFs are formulated with linear alpha olefins (LAO) and isomerized olefins (IO), or ester-based. Since SBF cuttings proved not to be environmentally superior to cuttings with OBF and in particular had a negative effect on sediment oxygen conditions, SBF as gradually phased out, also due to tightened OSPAR regulations (OSPAR, 2000b).

In 2018 approximately 2.5 tonnes of OBF was discharged, containing 0.05% OPF, resulting in the discharge of 125 kg of OPF in the whole OSPAR region. Nowadays most discharges take place from drilling using WBF, since the use of OBF and SBF has been gradually phased out (Bakke et al., 2013). Environmental monitoring has not found any adverse effects on benthic fauna over 250m from the installations, however it is still unclear what the environmental effects of discharges are over the long term (Bakke et al., 2013).

3.3 Cuttings piles

Cuttings piles consist of solid material on the sea-bed arising from drilled rock together with any adherent drilling fluids. Therefore, the chemical composition of the cutting piles is directly related to the composition of the drilling fluid used. Cuttings piles accumulated from drilling with WBFs generally do not pose a potential for significant environmental effects (IOGP 2016, Bakke et al 2013). Their toxicity is low compared with OBF, but particle sedimentation can have a local influence on marine life. Bakke et al. (2013) stated that old, polluted cuttings piles still exist, stating that in the North Sea 79 large and 66 small cuttings piles have been identified. Environmental risks of cutting piles may become an issue, especially during the decommissioning phase of installations (Shell, n.d.).

Recently OSPAR has assessed the environmental risk of the disturbance of cuttings piles during decommissioning (OSPAR, 2019C). In this report it is stated that leaving the piles in situ to degrade naturally is generally the best option. However, disturbance during decommissioning may be unavoidable and therefore there is a need to better understand the options available to manage drill cuttings during decommissioning and how they could impact the environment. These options are for the greater part determined by the unique circumstances of every decommissioning situation, like

- the local environmental circumstances (geology, water depth, hydrological circumstances),
- the chemical legacy left behind in the cutting piles (which drilling fluids were used in the past, and which chemicals were associated with these fluids).

Contamination within drill cuttings piles is case by case very specific, and therefore very heterogeneous and can be difficult to characterize. Further details of contaminants typically found in cuttings piles are provided in the following sections.

Hydrocarbons in the cuttings piles are derived mainly from OBF or SBF based fluid and may include:

- Diesel – mixture of saturated and aromatic hydrocarbons in the range C9 to C25;
- More refined mineral oil distillates, predominantly C10 to C21 alkanes;
- First generation synthetic base fluids such as esters, ethers, poly alpha olefins and acetyl;
- Second generation synthetic base fluids such as linear alpha olefins and internal olefins.

Before regulations were introduced in relation to the discharge of drilling muds, hydrocarbon contamination at some fields could be detected out to 5 - 10 km distance (Bakke et al., 2013). The quantity and integrity of hydrocarbons still remaining in the piles is a result of the piles' depleted dissolved oxygen content, the type of drilling fluids used, the low temperatures, and the resulting reduction in the numbers and composition of benthic communities present due to cuttings deposition, called smothering. The balance between oxygen transport processes and the chemical reactions occurring within the cuttings piles effectively determines the rate of degradation and the ultimate fate of hydrocarbons in the piles. Typically, aerobic biodegradation of hydrocarbons occurs only in the upper few millimeters of the pile. Anaerobic degradation may take place down to at least 20 - 50 cm but very slowly, with oil in the deeper parts of the pile remaining essentially unchanged.

The key hydrocarbon components potentially present in cuttings piles are:

- Total Hydrocarbon Concentration (THCs) which is the basic parameter used to estimate the total amount and distribution of oil present; and
- PAHs of which the 4 to 6 ring compounds are of particular importance due to their toxic nature even at very low concentrations.

Other hydrocarbons that may also be present in cuttings piles include:

- Alkyl phenols and alkyl phenol ethoxylates (APEs) which are suspected endocrine disruptors. Alkyl phenols are natural constituents of petroleum and can be found in produced water discharges. APEs were previously used as surfactant additives in drilling fluids;

- Polychlorinated biphenyls (PCBs), synthetic mixtures of chlorinated hydrocarbons, which are known endocrine disrupters and were used on North Sea installations prior to the mid-1980s;
- Mono, di and tri-butyltins (M/D/TBT) which are highly toxic, very persistent in the environment and known endocrine disruptors. TBT was used in antifouling paint until the mid-1980s.

There is also a concern that biodegradation and other diagenetic processes in the piles over the years may have produced other potentially toxic compounds such as complex esters and organic acids which until recently could not be identified analytically (Bakke et al, 2013).

The metals of greatest concern in the cuttings piles, because of their potential toxicity and/or abundance in drilling muds, are arsenic (As), barium (Ba), chromium (Cr), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn), (Breuer et al., 2004). The mineral barite (BaSO4) is one of the main constituents used in drilling mud resulting in high levels of Ba in cuttings piles.

In Appendix B an overview of actual monitoring results for substances and metals of concern at a number of cuttings piles is displayed. These results show that there is no consensus on which substances and metals should be monitored and in addition the concentrations may differ substantially between cuttings piles. Information from desktop studies may underestimate contamination. Therefore, no justified and reliable calculation of potential loads can be performed. For improvement of information on contamination from cuttings piles regulators could be contacted for sample results from decommissioning projects.

3.4 Accidental spills

Spills are accidental emissions, which can be divided into oil and chemical spills.

Over the period 2009-2018, the number of accidental spills of **oil** to sea varied widely within the OSPAR region, with 2014 having the highest number of spills (572) and 2017 having the lowest (402). There is no particular trend in the number of spills being reported. The total quantity spilled each year is variable with a high of 541 tonnes in 2012 when a single large spill in the UK contributed approximately 400 tonnes to the total and a low of 44 tonnes in 2016, see Table 2 for an overview of the quantity of oil spilled from 2009-2018. In 2018, oil spills contributed less than 2% in weight of the dispersed oil discharged or spilled to the OSPAR maritime area. There has been a downwards trend in the quantity of oil spilled annually, though as was the case in 2012, a single large event can negatively impact that trend (OSPAR, 2018). The number of oil spills from oil and gas installations reported by Germany is zero (OSPAR, 2020a).

Table 2: Quantity of oil spilled in tonnes per year, 2009 – 2018* (OSPAR n.d. b)

Quantity of oil spills	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Denmark	6	2	1	2	3	45	2	1	3	23
Germany	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	1	0	0	0	0	0	0
Netherlands	23	0	1	0	1	0	1	1	0	0
Norway	96	111	19	16	40	143	40	17	12	310

Quantity of oil spills	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Spain	0	0	0	0	128	0	0	-	-	-
United Kingdom	54	23	498	522	172	41	39	26	53	27
Total	179	137	519	541	3	230	82	44	68	81

*Adapted from the yearly OSPAR reports on Discharges, Spills and Emissions from Offshore Oil and Gas Installations from 2009-2019, available via https://odims.ospar.org/en/search/?datastream=discharges_oil_and_gas (OSPAR, n.d. b).

In addition to the discharges of man-made chemicals associated with the discharges of produced water, these chemicals are also accidently spilled. In 2018, 1.059 tonnes of chemicals were accidentally spilled, compared to a high of 13.940 tonnes in 2009 and a low of 757 tonnes in 2011. There is a decreasing trend in the number of chemical spills from 2014 onwards, however the quantity spilled is variable with no real trend over the 2009 – 2018 period. Of the chemicals spilled in each year the vast majority were on the PLONOR list (90% in 2018) or were ranking chemicals (9.5% in 2018). Table 3 displays the number of chemicals spilled in each class over the years (OSPAR 2018). In the period from 2009-2018 Germany has not reported any accidental spills of chemicals from oil and gas installations (OSPAR, 2018). For comparison, in 2019 a total of 2768 cubic meters of chemicals/man-made substances hazardous the water were reported to be spilled and ended up in the environment due to accidents from different industries in Germany (UBA, 2021).

Table 3: Quantity of chemicals spilled in kg per year from 2009-2018* (OSPAR, n.d. b).

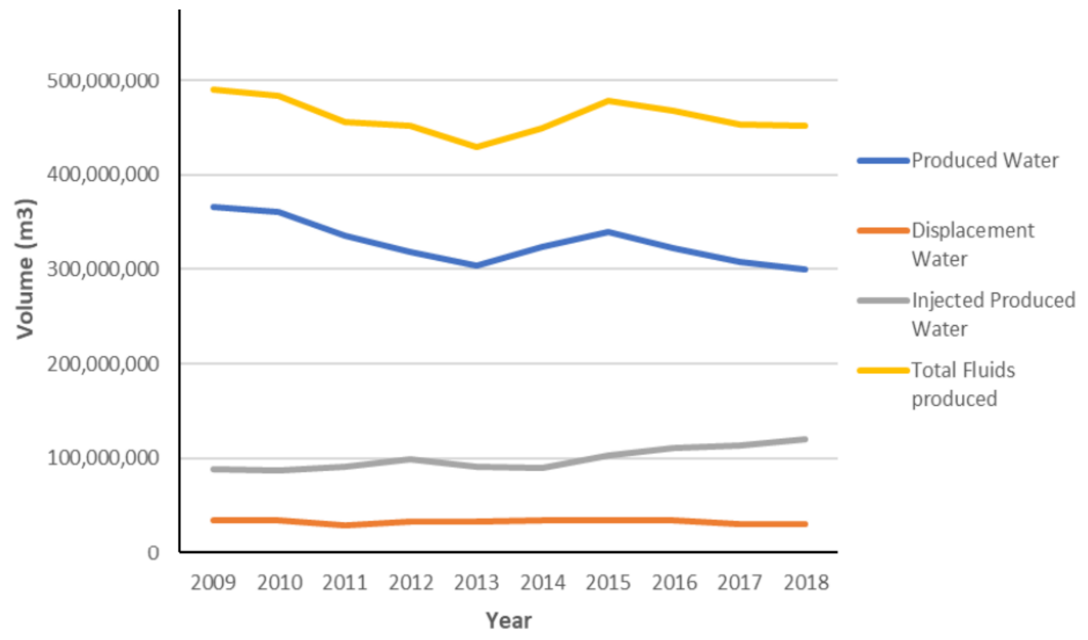
Prescreening category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
PLONOR	7,251,474	1,001,352	621,219	1,351,550	1,201,755	705,579	844,65	623,859	990,073	951,137
List of Chemicals for Priority Action	1,6	0	0	0	0	0	8	0	0	0
Inorganic LC_{50} or EC_{50} < 1 mg/l	0	863	0	72	0	360	0	186	247	144
Biodegradation < 20%	353,271	2,123	1,59	16,785	9,027	3,361	9,913	12,79	1,659	1,498
Substance meets two of three criteria	244	31,129	1,251	17,223	3,016	3,573	5,913	1,844	5,814	1,189
Inorganic, LC_{50} or EC_{50} > 1 mg/l	3,217	108	328	1,014	472	171	242	1,96	242	3,81
Ranking[1]	6,330,759	250,475	133,103	1,270,125	1,180,123	220,305	363,842	165,736	138,246	101,545
Total	**13,940,565**	**1,286,050**	**757,491**	**2,656,769**	**2,394,393**	**933,349**	**1,224,568**	**806,375**	**1,136,282**	**1,059,323**

*Adapted from the yearly OSPAR reports on Discharges, Spills and Emissions from Offshore Oil and Gas Installations from 2009-2019, available via https://odims.ospar.org/en/search/?datastream=discharges_oil_and_gas (OSPAR, n.d. b).

3.5 Produced water

Produced water is extracted together with crude oil from oil and gas wells. As wells age there is less oil/gas as production depletes the reservoir, therefore the production rates of produced water usually increase over time. For gas reservoirs increased produced water levels increase the need for hydrate inhibition, which is a major issue for some subsea systems. Based on OIC reporting, produced water (PW) is considered as the main source of hazardous substances emitted to the marine environment by the offshore oil and gas industry, a by-product of resource extraction. For example, PW contains 95-99% of the total amount of oil discharged in the marine environment from the oil and gas industry, according to Assessment of the OSPAR Report on Discharges, Spills and Emissions from Offshore Installations 2009 – 2018 (OSPAR, 2020a). Figure 5 displays the amount of PW and displacement water emitted to the marine environment in the OSPAR Region. The function and environmental impact of displacement water is already explained in section 3.1. In 2017, the amount of PW was 307,723,365 m^3, from which 113,838,307 m^3 was re-injected, which is 37% of the total amount of PW. In the oil industry, water injection is where water is injected into the oil reservoir, to maintain the pressure or to drive oil towards the wells, and thereby increase production. Produced water can also be injected into disposal wells to dispose of it without discharging into the sea. This reduces the potential of causing formation damage due to incompatible fluids, although the risk of scaling or corrosion in injection flowlines or tubing remains. Also, the residual non re-injected produced water, being contaminated with hydrocarbons, solids and other chemicals, , must be disposed of in some manner. The most common way to dispose of PW is by injection into permitted salt water disposal (SWD) wells or by reinjection into conventional reservoirs. Due to seismic hazards injection in deep wells is challenging (Rodriguez et al., 2020). Other disposal methods include, amongst other, transportation onshore or discharge in seawater. In comparison, the amount of drilling fluids discharged to the sea was 302,000 kg in 2017 (Organic Based and Oil Phase fluids combined), which is approximately 0.01% of the amount of PW (OSPAR, 2019).

Figure 5: Volumes of Produced and Displacement water in the OSPAR region during the period 2009-2018.



source: https://www.ospar.org/documents?v=43787? (OSPAR, 2020a)

Much research is available on the composition of PW and the hazards associated with these compounds (i.e. Balaam et al., 2009; Neff et al., 2011; Smit et al, 2011; Parkerton et al., 2018). Although the composition of PW may be different between installations, because of the age, type (oil/gas) or location of the installation, several compounds are detected in every sample. Offshore PWs contain a complex mixture of naturally occurring organic and inorganic substances, including suspended particles (e.g., clay), dispersed oil (tiny oil droplets), dissolved organic compounds, dissolved hydrocarbon gases, inorganic salts, heavy metals, and naturally occurring radioactive materials (NORM). Internationally, hundreds of reports are available containing chemical composition data of PW discharges. A broad summary is provided by Lee and Neff (2011).

In 2019 the Norwegian Environment Agency assessed environmental effects of offshore produced water discharges for the Barents Sea. They typically found modest responses in fish and mussels when they are kept in the water column relatively close to the oil and gas installation and in repeated field monitoring surveys in the North Sea. These results do not indicate that there are significant adverse effect of PW occurring in ecosystems downstream of the oil and gas installations (Beyer et al., 2019).

In the following chapters more information is given on man-made chemicals in produced water and naturally occurring chemicals in produced water.

3.5.1 Man-made offshore chemicals in produced water

Next to the naturally occurring substances, chemicals used to facilitate separation of oil and gas from water or prevent hydrate, corrosion or scale formation may be released within discharges like PW. These chemicals are often added to the crude oil which is extracted from the well or into the gas/gas condensate well streams. A substantial fraction of these chemicals may unavoidably be emitted to the marine environment together with the produced water. From these, biocides, corrosion inhibitors and hydrogen sulphide inhibitors are used the most (EOSCA, personal communication). These added chemicals are man-made chemicals as they do not naturally occur in the produced water. Most of these added chemicals are drilling chemicals, whereas others are added to the production process, these are called production chemicals (Beyer et al., 2019). In PW the chemical are invariably production chemicals, as the wells have been drilled beforehand there is no need for application of drilling chemicals.

Data on individual man-made chemicals is not available for this study, as this information is either confidential or only the material is known without including information on the composition of individual substances. For this study we received information on drilling permits from Denmark, including the offshore chemicals approved by the Danish government (personal communication). The lists of chemicals did not include any usage data, such as the chemical use or information with regards to volumes or quantities of the chemicals, or information on individual substances. Additionally, we received information on man-made chemicals from the UK which includes thousands of products, but information on individual substances or material safety data sheets (MSDS) is not given at all. Finally, we contacted the OSPAR secretariat (personal communication) about summarized data on man-made chemicals, however this information is currently not available via OSPAR. For these reasons, the OSPAR information on total man-made chemical from the offshore oil and gas industry is used to provide a rough overview of the use of these chemicals. In 2016 a total of 188.420 tonnes man-made chemicals were discharged, see Table 4 (OSPAR, 2020a), from which 83% were PLONOR chemicals and 15% were ranking chemicals (as explained in paragraph 2.1.2). From all discharged chemicals in 2016 only 1% contained substitution chemicals, chemicals which are or contain substances that are candidates for substitution. Only 0,0067% of the discharged man-made chemicals originated from Germany, compared to almost 55% originating from Norway and over 30% originating from the UK. In 2016 Germany did not discharge any substitution chemicals. This percentage may increase if Germany would increase their share in offshore oil and gas activities. For comparison: in 2016 Germany had only two offshore oil or gas production installations and Norway and the UK respectively had 63 and 281 installations (OSPAR, 2020a).

A recent study by Parkerton et al. (2017) has shown that manmade chemicals are negligible contributors to the overall risk in produced water. From the substances identified, a number of Polycyclic Aromatic Hydrocarbons (PAH) and mercury appeared to pose the highest risk.

In another study however different results were achieved. Based on chemical analysis of PW from 25 different Norwegian platforms and toxicological data (LC50/EC50), de Vries & Jak (2018) estimated the relative contribution from individual substance groups to the overall hazards. For most platforms the substance-based hazard was dominated by the combined group of production chemicals, the aliphatic hydrocarbons and the organic acids. Averaged over all 25 platforms; production chemicals contributed 41% to the total hazard, aliphatic hydrocarbons contributed 26%, organic acids 24%, BTEX 5%, phenols 1.5%, PAHs 1.2%, naphthalenes 0.5% and metals (0.3%) (these calculations are based on Table 5.1 in de Vries & Jak (2018). Based on the information from this report production chemicals could be a significant hazard for the marine environment, however, due to a lack of information we are currently not able to determine how big this hazard could be.

The composition of produced water may vary per field and determining the overall contribution of man-made chemicals from produced water to the total hazard of offshore oil and gas is therefore difficult.

Table 4: Quantity of man-made offshore chemicals discharged in kg/year for the year 2016 (OSPAR, 2017b).

Country	PLONOR[1]	LCPA[2]	Inorganic, LC50 or EC50 < 1 mg/l	Biodegradation < 20 %	Substances meet two of three criteria[3]	Inorganic, LC50 or EC50 > 1 mg/l	Ranking[4]	Total
Denmark	12,160,682	0	18,247	460	6,517	223,153	4,664,838	17,073,897
Germany	12,299	0	0	0	0	0	339	12,638
Ireland	13,839	0	0	0	0	0	22	13,861
Netherlands	8,313,274	0	0	261	5,826	62,314	272,207	8,653,882
Norway	89,022,868	0	74,639	20,316	11,087	0	14,231,540	103,360,450
Spain								
United Kingdom	47,614,750	3	120	472,358	819,485	365,463	10,033,343	59,305,522
Total	157,137,712	3	93,006	493,395	842,914	650,930	29,202,289	188,420,250

[1] Pose Little or No Risk to the Environment (OSPAR, 2021c)

[2] List of Chemicals for Priority Action (OSPAR, n.d. d)

[3] Substances which meet two of the following three criteria:

- biodegradation less than 60%;
- BCF larger than 100 or Log Pow ≥ 3;
- LC50/EC50 less than 10mg/L.

[4] Ranking chemicals being the combination of inorganic chemicals with LC50 or EC50 greater than 1 mg/l and ranking chemicals, which includes substances ranked according to OSPAR Recommendation 2000/2 and don't fall into another category.

In the following box the most important classes of man-made offshore chemicals are mentioned.

Classes of man-made Production Chemicals used in the Offshore oil& gas industry

Natural-gas hydrates are ice-like solids that form when free water and natural gas combine at high pressure and low temperature. This can occur in gas and gas/condensate wells, as well as in oil wells. ***Hydrate inhibitors*** are chemical substances designed to control the formation of hydrates during natural gas production at an oil or gas condensate well. The most common of the hydrate inhibitors are methanol (MeOH) and glycols such as monoethylene glycol (MEG).

Oilfield scaling is the precipitation and accumulation of insoluble crystals (salts) from a mixture of incompatible aqueous phases in oil processing systems. ***Scale inhibitors*** are specialty chemicals that are added to oil production systems to delay, reduce and/or prevent scale deposition. Acrylic acid polymers, maleic acid polymers and phosphonates have been used extensively for scale treatment in water systems due to their excellent solubility, thermal stability and dosage efficiency.

Corrosion is the destructive attack of a material by reaction with its environment and a natural potential hazard associated with oil and gas production and transportation facilities. For his purpose ***Corrosion inhibitors*** are used. These are surfactants which give them properties allowing them to partition between the oil and water phase. The hydrophilic group adsorbs onto the metal surface, which leaves the hydrophobic group to form a water-resistant organic film on the surface. It is this film that prevents the corrosive species from encountering the metal surface. Internal corrosion of product pipelines can be controlled with coatings and inhibitors (a few parts per million) such as amines and nitrites. This class of corrosion inhibitors differs from the corrosion inhibitors used to protect the structure from the installation itself.

Hydrogen sulphide is a colourless, flammable, and toxic gas prevalent in the hydrocarbon processing industry. ***Hydrogen sulfide scavengers*** are specialized chemicals that are widely employed in the removal of soluble sulphide species from the oil and gas. An ideal scavenger is expected to cause neither corrosion nor fouling issues. In real time, the scavenger or its reaction products can have corrosion inducing or inhibitive properties. A scavenger may synergistically or antagonistically affect the performance of a commercial corrosion inhibitor. Zinc compounds are commonly used to precipitate ZnS and decrease the concentration of all sulphides.

Biocides are used in the offshore oil and gas industry to maximize production by protecting assets through the inhibition of microbial induced biofilm and corrosion. They are used in small amounts to control the growth of bacteria and other harmful organisms in the wellbore.

3.5.2 Naturally occurring substances in produced water

During the development and implementation of OSPAR Recommendation 2012/5 for a risk-based approach to the Management of Produced Water Discharges from Offshore Installations (OSPAR, 2012) (see also the box below on Risk Based Approach), research has been conducted on methodologies to assess the environmental risk of PW. Data from chemical analyses of PWs over years have yielded a list of substances that are of high relevance to environmental monitoring. Therefore, extended chemical analyses have been performed on a total of 28 offshore installations in the OSPAR region, originating from four different OSPAR contracting parties, namely Denmark, United Kingdom, Norway and the Netherlands. The list of compounds that was analysed was compiled from the lists received from the different Contracting Parties. Based on the results of the chemical analyses and the PBT criteria of the compounds a list of compounds causing the highest risk is identified. This list can be found in the background document (OSPAR, 2013) and in Annex 1 of this report.

Risk Based Approach

Up till 2010, OSPAR has focused on oil in produced water and the application of Best Available Technique (BAT) and Best Environmental Practice (BEP), but discharges of produced water contain other substances, such as heavy metals, aromatic hydrocarbons, and alkyl phenols which are present in the hydrocarbon reservoir, and added chemicals that are used during the production and produced water treatment processes. All substances present in the produced water will contribute to the total risk resulting in a need to move towards a more holistic approach and in 2012 OSPAR adopted a Recommendation for a Risk-based Approach (RBA) to the Management of Produced Water Discharges from Offshore Installations (RBA Recommendation) (OSPAR, 2012) and associated Guidelines.

The RBA should determine the magnitude of the total risk and, where appropriate, which substance or group of substances contributes most to the total risk, and whether exposure levels in the receiving environment relating to the discharge, or specific components of the discharge, indicate that the risk is adequately controlled, so that Contracting Parties can take the most effective risk reduction management measures. The risk will be characterised based on a combination of Whole Effluent Assessment (WEA) studies and/or an assessment of the individual substances or groups of substances, identified in the produced water, taking account of the exposure relating to the discharge and the sensitivity of the receiving marine environment. Whole Effluent Assessment (WEA) refers to a suite of tests used to characterise the quality of an effluent before, during and after discharge, as stated by Concawe (Concawe, 2014). RBA approaches vary per country, making it difficult to compare the data. If the risk is not considered to be acceptable, appropriate measures based on BAT and BEP will be required to be implemented by industry to avoid or minimise the risk. While RBA cannot be used as basis for an assessment of the actual impact of Produced Water (PW) in the marine environment, the results can be used as a tool to target the different investigations of such impacts in the sea around the offshore installations.

This approach is implemented for all offshore installations with produced water discharges in the OSPAR maritime area.

3.5.2.1 From chemical analysis to loads for OSPAR region

The results of the chemical analysis can be used to evaluate total loads for these substances for the total OSPAR region. Two different approaches for this extrapolation are described here, and based on the limited data available for substances, a preferable method was chosen.

- **Method 1: Extrapolation of individual loads of installations**

For 23 of the 28 installations investigated, also annual volumes of PW for the year 2010, the year of sampling were provided by the Contracting Parties. Based on the concentrations measured and the flow data of discharged PW of these installations, a total annual load per installation for each of the compounds measured can be calculated:

$$total\ annual\ load = measured\ concentration * annual\ volume$$

By summing up the total annual load for all compounds for all 23 installations, the total load for the year 2010 of these compounds for these 23 installations can be calculated.

In a next step the total volume of PW of these 23 installations was compared with the total volume of PW discharged in the OSPAR region in 2010 according to OSPAR (2012b). The total flow of PW of the 23 installations monitored in 2010, consisted of 25,2 % of the total volume discharged in 2010. Based on this percentage, the annual load of the identified substances was extrapolated for the whole OSPAR region.

- **Method 2: Using average measured concentrations**

The second approach was more straightforward. In this approach the average measured concentration per substance of the 28 installations monitored was used. This average concentration was multiplied with the total volume of PW for the whole OSPAR area discharged into the marine environment according to OSPAR (2012b).

- **Comparison of both methods**

In order to choose a preferred method, the outcome of two methods with the data available in the OSPAR annual reports was compared, namely estimates of the BTEX (Benzene, Toluene, Ethyl-benzene, Xylene) loads in the OSPAR region. In 2016 OSPAR estimated that a total amount of 4.532 tonnes of BTEX was discharged. Using method 1, a total amount of 6.573 tonnes of BTEX was calculated, while method 2 resulted in a total load of 10.708 tonnes of BTEX. These results show that the calculation methods differ from the reported BTEX values with a factor 1.5 (method 1) and 2.4 (method 2). The calculations are shown in Appendix A.1. In chapter 4 the total loads of emitted chemicals are based on the average measured concentrations (method 2).

3.6 Corrosion protection

Sacrificial anodes with zinc are used to protect the offshore installations from corrosion, therefore the emission from zinc from corrosion protection is an additional source of potentially hazardous substances into the environment. The corrosion protection system is known as Cathodic Protection (CP) and operates on the principle that electrons are removed from the zinc anode and transferred by the seawater (acting as an electrolyte) are deposited on the steel plate which has now become the cathode thus protecting it against corrosive attack. The essential metal used in the offshore oil and gas industry, zinc, differs from the essential metal used in the offshore wind energy sector, aluminium, which is more environmentally friendly. Based on the (confidential) reports of 13 individual Dutch installations for the European Pollutant Release and Transfer Register (E-PRTR), it was estimated that the zinc emission approximately equals the emission of zinc via PW (E-PRTR, 2020). E-PRTR is the Europe-wide register that provides easily accessible key environmental data from industrial facilities in European Union Member States (European Industrial Emissions Portal, n.d.). Although the nature of both emissions differs; the emission originating from sacrificial anodes depends on the age and size of the installation, whereas the emission from PW depends, amongst others, on the age, size and location of the well. These differences were also reflected in the ratio between the two zinc emissions for which both sources were reported, see Table 5. However, the average ratio was close 0,86, indicating that the emissions originating from PW are comparable to those originating from sacrificial anodes. For the moment we assume that sacrificial zinc anodes are also used on the rest of the installations in the OSPAR region, and that the ratio of approximately 1 also applies to the rest of the installations.

Table 5: Zinc emissions for some Dutch installations originating from produced water or sacrificial anodes in 2019.

Installation (anonymised)	Zinc emmission via PW (kg/year)	Zinc emission via anodes (kg/year)	Ratio
Gas A	3076.42	1600.00	1,92
Oil A	183.20	900.00	0,20
Gas B	2522.00	1032.00	2,44
Oil B	97.30	85.80	1,13
Gas C	57.80	858.00	0,07
Gas D	98.18	229.00	0,43
Gas E	54.90	299.00	0,18
Gas F	38.47	78.46	0,49
		average	**0.86**

4 Results substance assessment

4.1 Overview of natural occurring substances in Produced Water (PW)

An overview of the loads of natural occurring substances in Produced Water for which a total load in the OSPAR region could be calculated is included in Appendix A.1, ordered from the highest to the lowest loads. In Table 6 the total loads are calculated using method 2: using average measured concentrations, as described in chapter 3.5.2.1. In this approach the average measured concentration per substance of the 28 installations monitored was used. This average concentration was multiplied with the total volume of PW for the whole OSPAR area discharged into the marine environment according to OSPAR (2012b). The discharge of zinc from sacrificial anodes was calculated by multiplying the discharge from Produced Water by the ratio determined in Table 5 (0.86). As no quantitative data are available for the other sources (spills, drilling fluids, cutting piles and man-made chemicals in PW) the quantitative results in this report focus on natural occurring substances found to be relevant for PW. Zinc was added as it is emitted from sacrificial anodes.

Table 6: Overview of total estimated discharges of natural occurring substances in Produced Water and zinc from sacrificial anodes from offshore oil and gas industry (tonnes/year) in the OSPAR region. All discharges originate from Produced Water, except zinc from sacrificial anodes. The total discharge from Produced Water was calculated by method 2 as explained in 3.5.2.1. The discharge of zinc from sacrificial anodes was calculated by multiplying the discharge from Produced Water by the ratio determined in Table 5 (0.86).

Substance	Total Discharge (tonnes/year)	Substance	Total Discharge (tonnes/year)
Zinc	2173	Acenaphtylene / acenaphtene	5,2
Zinc from sacrificial anodes[1]	1869*	Cadmium	5,15
Phenol	1304	C1-dibenzothiophenes	5,1
Sum C1-C3 phenols	9845	Mercury	4,78
Lead	264	Fluorene	4,49
Naphtalene, phenanthrene, dibenzothiphene	241	Toluene	3,31
C3-naphtalenes	154	Copper	3,01
C2-naphtalenes	140	Nickel	2,2
1-methylnaphtalene	118	Dispersed oil (C10-C40)	1,22
C1-naphtalenes	117	Acenaphtene	0,97
Naphtalene	10	Xylenes	0,96
2-methylnaphtalene	88.79	B(a)anthracene / chrysene / triphenylene	0.34
Sum C4-C5 phenols	46.16	Acenaphthylene	0.32

Substance	Total Discharge (tonnes/year)	Substance	Total Discharge (tonnes/year)
C1-phenanthrenes	36.75	Chrysene	0.3
Total Hydrocarbons	29.9	Ethylbenzene	0.26
C2-phenanthrenes	24.27	Pyrene	0.25
C3-phenanthrenes	19.95	Fluoranthene	0.16
Sum C6-C9 Phenols	16.55	Dispersed oil (C7-C10)	0.15
Arsenic	12.97	Anthracene	0.13
C2-dibenzothiophenes	9.76	Benzo(a)anthracene	0.08
C3-dibenzothiophenes	9.58	Benzo(b)fluorantene	0.07
Phenanthrene	9.32	B(a+e)p/perylene	0.04
Dipenzothiophene	7.92	B(ghi)perylene	0.02
Chromium	7.4	Benzo(a)pyrene	0.02
Phenathrene / anthracene	6.21	Benoz(k)fluorantene	0.01
Benzene	6.18	Dibenz(a,h)anthracene	0.01
Dispersed oil (C7-C40)	6.16	Indenol(123cd) pyrene	0.01

[1] The discharge of zinc from sacrificial anodes was calculated by multiplying the discharge from Produced Water by the ratio determined in Table 5 (0.86).

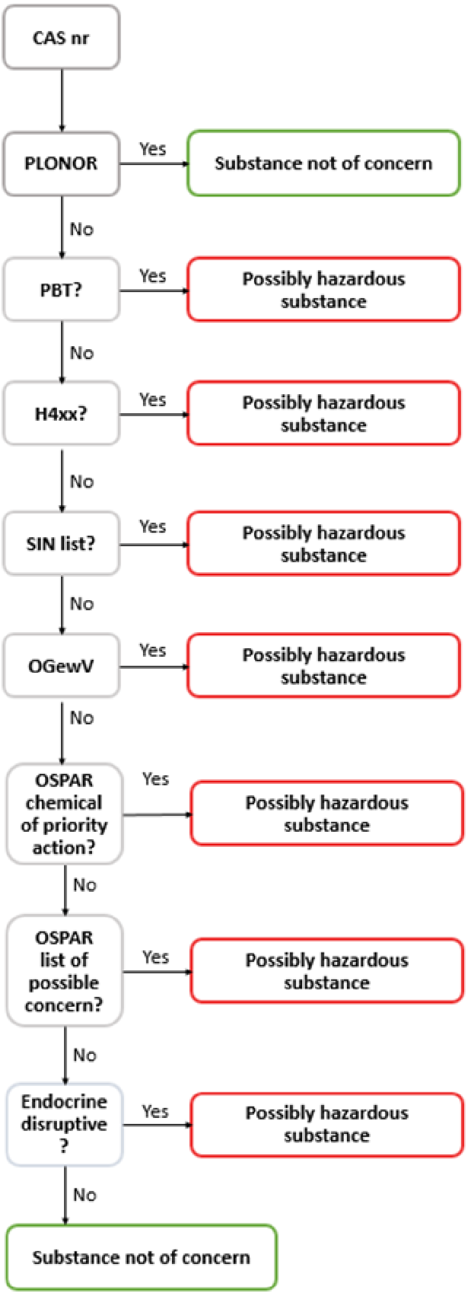
4.2 Identification of hazardous substances

For all individual substances listed in Table 6, physical/chemical characteristics (Persistency, Bioaccumulation and Toxicity, PBT) according to ECHA (ECHA, n.d. a), and other relevant parameters, such as the risk classification were selected and compiled. The risk classification was based on GHS-classification (Globally Harmonized System of Classification and Labelling of Chemicals) (United Nations, 2021) and H-phrases (Hazard phrases) according to CLP (Classification and Labelling of Chemicals) Regulation (European Commission, 2008). For most substances, information was available from the ECHA (European Chemicals Agency) website (ECHA, n.d. a). In the case that an ECHA registration dossier as well as an ECHA substance information file are available, the information from the registration dossier was consulted. In the chemical analysis performed, some of the substances were only measured as a group (i.e. Sum C4-C5 Phenols, Naphtalenes. Phenathrenes, Dibenzothiophenes). In development of the Risk Based Approach (RBA) within Offshore Industry Committee (OIC), these groups were assigned to individual substances, regarded to be a valid representative for this group, thereby assuming a worse-case scenario. This indicates that the compound with the lowest PNEC was used to act as a representative for this group of substances. The list of PNEC's and reasoning behind the grouping can be found in OSPAR (2013).

Not all of the 32 substances listed in Table 6 are expected to be harmful to the aquatic environment, however, some substances are. A distinction between hazardous and non-hazardous substances is therefore required. Substances that occur on the OSPAR list of substances which Pose Little or No Risk to the Environment (PLONOR) are expected not to be hazardous and can be disregarded (OSPAR, 2021c). However, some substances on the PLONOR list are regarded as hazardous in German legislation (AwsV, 2017). Possibly hazardous substances are identified by being PBT, having a hazard-phrase (H-phrase) related to aquatic toxicity (H4xx), with occurrence on the SIN-list (ChemSec, n.d.), OSPAR list of possible concern (OSPAR, n.d. e), OSPAR list of chemical of priority action (OSPAR, n.d. d) or the ECHA list of endocrine disruptive substances (ECHA, n.d. b). Additionally, the identified substances are crosschecked with the river basin specific pollutants and priority substances respectively listed in Annex 6 and 8 of the German Ordinance on the Protection of Surface Waters (OGewV, 2016), which represents the national implementation of the priority substances of the Water Framework Directive 2013/39/EU (EU-Directive 2013/39/EU). These hazard criteria are explained in chapter 4.2.1 – 4.2.4.

In the flow diagram below (Figure 6) the identification of possibly hazardous substances is illustrated. Only substances that are on the SIN-list, OSPAR list of possible concern, OSPAR list of chemicals for priority action, the ECHA list of endocrine disruptive substances, the river basin specific pollutants and priority substances listed in the German Ordinance on the Protection of Surface Water (Annex 6 and 8 OGewV) or which have an H-phrase to do with aquatic toxicity are identified as possibly hazardous substance.

Figure 6: Flow diagram for identification of possibly hazardous substances as determined and applied in this study.



Source: own illustration, Deltares

4.2.1 PBT criteria

PBT refers to Persistent, Bioaccumulative and Toxic. PBT substances are strictly regulated and therefore substances should be assessed according to these criteria. In this study the PBT assessment as performed by ECHA was used to determine the persistence, bioaccumulation potential and toxicity of a substance. In the table below an example of the criteria that are used to assess a substance are described. For more information on PBT assessment please check the Guidance on Information Requirements and Chemical Safety Assessment Chapter R.11: PBT/vPvB assessment (ECHA, 2017). 5 of the total 32 substances are PBT substances, namely fluoranthene, benzo[a]anthracene, chrysene, 4-ter-octylphenol and benzo[ghi]perylene.

Table 7: PBT criteria as enforced by ECHA (ECHA, 2017), in accordance with section 1 of Annex XIII of the REACH regulation 1907/2006 (European Commission, 2006).

Property	PBT criteria
Persistance	A substance fulfils the persistence criterion (P) in any of the following situations: (a) the degradation half-life in marine water is higher than 60 days; (b) the degradation half-life in fresh or estuarine water is higher than 40 days; (c) the degradation half-life in marine sediment is higher than 180 days; (d) the degradation half-life in fresh or estuarine water sediment is higher than 120 days; (e) the degradation half-life in soil is higher than 120 days.
Bioaccumulation	A substance fulfils the bioaccumulation criterion (B) when the bioconcentration factor in aquatic species is higher than 2000.
Toxicity	A substance fulfils the toxicity criterion (T) in any of the following situations: (a) the long-term no-observed effect concentration (NOEC) or EC10 for marine or freshwater organisms is less than 0.01 mg/L; (b) the substance meets the criteria for classification as carcinogenic (category 1A or 1B), germ cell mutagenic (category 1A or 1B), or toxic for reproduction (category 1A, 1B or 2) according to Regulation EC No 1272/2008; (c) there is other evidence of chronic toxicity, as identified by the substance meeting the criteria for classification: specific target organ toxicity after repeated exposure (STOT RE category 1 or 2) according to Regulation EC No 1272/2008.

4.2.2 H-phrases

H-phrases are used to describe potential hazards with regards to a specific substance (European Commission, 2008). All substances which have been assigned an H-phrase related to aquatic toxicity have been listed as possibly hazardous. These H-phrases are:

- H400: Very toxic to aquatic life.
- H410: Very toxic to aquatic life with long lasting effects.
- H411: Toxic to aquatic life with long lasting effects.
- H412: Harmful to aquatic life with long lasting effects.
- H413: May cause long lasting harmful effects to aquatic life.

21 of the total 32 substances have been assigned one or more of the above H-phrases.

Only substances with an H-phrase related to aquatic toxicity are identified as being potentially hazardous.

A risk classification, based on the Globally Harmonzied System of Classification and Labelling of Chemical (GHS-classification), was researched as well. GHS-classes include classes like toxic, (GHS06), long-term health hazard (GHS08) or hazardous to the aquatic environment (GHS09). In this study GHS classes are included, but the decision whether a substance is hazardous is based on hazard phrases (H-phrases), rather than GHS as the H-phrases represent more details in level of toxicity.

4.2.3 Substance classification lists

None of the 32 substances occur on the List of Substances/Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR) (OSPAR, 2021c). As explained in chapter 2.1.2 this list contains substances whose offshore use and discharge are subject to expert judgement by national authorities or do not need to be strongly regulated (OSPAR, 2021c). Some substances on the PLONOR list are regarded as hazardous in German legislation (AwsV, 2017), therefore occurrence on the PLONOR list does not necessarily mean that a substance is classified is not hazardous. 10 substances occur on the SIN-list (ChemSec, n.d.) due to their link to aquatic toxicity, amongst which mostly PAHs, phenols and heavy metals. The SIN list includes substances which should be substituted (ChemSec, n.d.). 10 substances occur on the OSPAR list of possible concern (OSPAR, n.d. e), for more information on this list please see chapter 2.1.2. 4 substances occur on the OSPAR list of priority action (OSPAR, n.d. d), namely cadmium, lead, mercury and 4-tert-octylphenol. 4-tert-butylphenol and 4-tert-pentylphenol are listed as endocrine disruptive chemicals by ECHA (ECHA, n.d. b). Lastly 4 substances are listed in Annex 6 of the OGewV (OGewV, 2016) and 11 substances are listed in Annex 8 of the OGewV (OGewV, 2016). The OGewV represents the national implementation of the priority substances of the Water Framework Directive (EU-Directive 2013/39/EU).

4.2.4 Overview of hazardous substances

Based on the abovementioned criteria 24 of the 32 substances have been categorized as being hazardous. In Table 8 an overview of these substances, including the total estimated loads from produced water and zinc from sacrificial anodes and the reason why they are deemed hazardous is included.

As can be observed from Table 8 all hazardous substances belong to three substance groups:

- aromatic hydrocarbons (benzene, toluene, naphthalene, acenaphtene, fluorene, anthracene, phenantrene, pyrene, benz[a]anthracene, chrysene, dibenzo[a,h]anthracene, benzo[a]pyrene, benzo[b]fluoranthene and benzo[ghi]perylene);
- heavy metals (arsenic, cadmium, nickel, mercury and lead);
- phenols (4-tert-butylphenol, 4-tert-pentylphenol, 4-tert-octylphenol and nonylphenol (C9 alkyl phenols representative)).

The highest hazardous chemical load is from lead (264 tonnes/year) followed by arsenic (12,97 tonnes/year) and naphthalene (10 tonnes/year).

In Annex A.2 the overview of all substances including information on PBT, H-phrases, GHS classes and occurrence on substance classification lists can be observed.

For 16 of the 24 identified substances measurements are measured in the marine environment. These measurements are carried out for the matrices water, sediment and biota and are expressed in either a concentration in µg/l (water) or µg/kg (sediment and biota). The measurement of the substances is based on measurements from the Meeresumweltdatenbank (MUDAB data bank), which is a marine environmental data bank. These substances can also originate from other sources than the oil and gas industry. In Table 8 a column is added to show which substances are measured in which matrices.

Table 8: Overview of emissions of hazardous substances in produced water and corrosion protection from offshore oil and gas industry.

CAS nr	Substance	Substance load (tonnes/year)	PBT criteria	Occurrence on substance classification list	Measurement in marine environment
71-43-2	Benzene	6.18	No	OGewV – Annex 8	Water
108-88-3	Toluene	3.31	No		Water
91-20-3	Napthalene	10[1]	No	SIN-list, OGewV - Annex 8	Water, sediment, biota
83-32-9	Acenaphthene	0.97	-		Water, sediment, biota
86-73-7	Fluorene	4.49	-		Water, sediment, biota
120-12-7	Anthracene	0.13	Possibly	OGewV - Annex 8, OSAPR list of possible concern	Water, sediment, biota
85-01-8	Phenanthrene	9.32	Possibly	OGewV - Annex 6	Water, sediment, biota
206-44-0	Fluoranthene	0.16	Yes	OGewV - Annex 8, OSAPR list of possible concern	Water, sediment, biota
129-00-0	Pyrene	0.25	-	OSAPR list of possible concern	Water, sediment, biota
56-55-3	Benz[a]anthracene	0.08	Yes	SIN-list, OSAPR list of possible concern	Water, sediment, biota
218-01-9	Chrysene	0.3	Yes	SIN-list, OSAPR list of possible concern	Water, sediment, biota
53-70-3	Dibenzo[a,h] anthracene	0.01	No	SIN-list. OSAPR list of possible concern	Water, sediment, biota
50-32-8	Benzo[a]pyrene	0.02	No	SIN-list, OGewV - Annex, OSAPR list of possible concern	Water, sediment, biota
7440-38-2	Arsenic	12.97	-	OGewV - Annex 6	Water, sediment, biota
7440-43-9	Cadmium	5.15	-	SIN-list, OGewV - Annex 8, OSPAR list of priority action	Water, sediment, biota

CAS nr	Substance	Substance load (tonnes/year)	PBT criteria	Occurrence on substance classification list	Measurement in marine environment
7440-02-0	Nickel	2.2	-	SIN-list, OGewV - Annex 8	Water, sediment, biota-
7439-97-6	Mercury	4.78	-	OGewV - Annex 8, OSPAR list of priority action	Water, sediment, biota
7439-92-1	Lead	264	-	OSPAR list of priority action	Water, sediment, biota
98-54-4	4-tert-butylphenol	-[2]	No	OGewV - Annex 8, OSAPR list of possible concern, ECHA endocrine disruptive list	-
80-46-6	4-tert-pentylphenol	-[2]	No	ECHA endocrine disruptive list	-
140-66-9	4-tert-octylphenol	-[2]	Yes	SIN-list, OSPAR list of priority action	Water, sediment
2515-52-3	Nonylphenol (C9 alkyl phenols representative)	-[2]	No	OSAPR list of possible concern	-
205-99-2	Benzo[b]fluoranthe ne	0.07	No	OGewV - Annex 8	Water, sediment, biota
191-24-2	Benzo[ghi]perylene	0.02	Yes	OGewV - Annex 8, OSAPR list of possible concern	Water, sediment, biota

[1] napthalene loads expressed as other naphthalene compositions is not shown here
[2] only sums of phenols are available

5 Conclusions

This report describes the potential emissions of hazardous substances originating from the offshore oil and gas industry for the OSPAR region during exploration, production, and decommissioning.

Various relatively small discharges showed no toxic effects

In this report various discharge types are discussed, see chapter 3. So far, various relatively small discharges with low environmental impact originating from the oil and gas industry are categorized as miscellaneous discharges. These discharges are considered to be small (Oil and Gas UK, 2018) and the combined efforts of a bioassay study and modelling showed no toxic effects of number of selected effluents on an oil installation in the surrounding environment (Hughes et al., 2019).

Discharges from drilling fluids are relevant, but decreasing; the total load of contaminants could not be determined in this study

Drilling fluids are discussed as possible source of contaminants, mainly with regards to the use of Oil-Based fluids (OBF). OBF cuttings used to contain low amounts of aromatic hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). However, due to the implementation of OSPAR decision 2000/3 on the use of Organic-Phase Drilling Fluids (OPF) (OSPAR, 2000b) and the discharge of OPF-Contaminated Cuttings prohibited the discharge of cuttings contaminated with OPF at a concentration greater than 1% by weight on dry cuttings and by other measures, the use of OPF was gradually eliminated. In 2018 approximately 2.5 tonnes of OBF was discharged, containing 0.05% OPF, resulting in the discharge of 125 kg of OPF in the whole OSPAR region. This amount has been decreasing over time and should be further reduced. Currently most discharges originate from drilling using water-based fluids (WBF), since the use of OBF and synthetic based fluids (SBF) has been gradually phased out (Bakke et al., 2013).

Cuttings piles accumulated from drilling with WBFs generally do not pose a potential for significant environmental effects (IOGP 2016, Bakke et al 2013). Cuttings piles accumulated from drilling with SBF and OBF may contain hydrocarbons, such as aromatic hydrocarbons (C9-C25) and alkanes (C10-C12). As mentioned before the use of SBF and OBF has been gradually phased out, however, as stated by Bakke et al. (2013), polluted cuttings piles sometimes still exist in the North Sea. Concentrations of various contaminants in cuttings piles have been determined in various studies (Genesis, 2016), however, the total load of contaminants from cuttings piles could not be determined in this study.

Produced water (PW) is considered to be the main source of hazardous substances from the offshore oil and gas industry

In 2018, oil spills contributed less than 2% in weight of the dispersed oil discharged or spilled to the OSPAR maritime area (OSPAR, 2018). Currently produced water (PW) is considered to be the main source of hazardous substances from the offshore oil and gas industry, for example, PW contains up to 99% of the total amount of oil discharged to the marine environment from the offshore oil and gas industry (OSPAR, 2020a). The total amounts of naturally occurring chemicals in produced water are up to 10,000 tonnes/year, calculated over a total of 23 oil and gas platforms. In reality the number of oil and gas platforms is almost 20 times higher, potentially resulting in much higher loads from the discharge of produced water. On the one hand, recent studies by Parkerton et al. (2017) showed that man-made chemicals are negligible contributors to the overall risk in produced water, on the other hand, De Vries & Jak (2018) identified that production chemicals could be a significant hazard for the marine environment.

Corrosion protection was identified to be a relevant source

Corrosion protection was identified to be a source of zinc release into the marine environment, with loads similar to those in produced water (confidential, E-PRTR).

Only individual substances from produced water and corrosion protection could be evaluated; the assessment of hazardous substances in this study is greatly hampered by a lack of data

For corrosion protection and naturally occurring substances in produced water quantitative data was found. For all other sources only qualitative information was available and no information on the individual hazardous substances. Most emissions originating from the oil and gas sector are a mixture of both naturally occurring materials and man-made chemicals added to these materials to facilitate processes. The composition of the naturally occurring materials varies and merely depends on environmental circumstances and the age of the reservoir. These aspects may hamper a good quantification of these materials. Only for the natural composition of produced water information seems to be available for a reasonable quantification. The composition of the man-made chemicals added to produced water and drilling fluids is hard to identify, as only meta-information regarding these substances is available. Product specific information is available for national permitting authorities. However, this information does not include information on the substances used in products neither their application. Therefore, it is not possible to determine the use of individual man-made chemicals within this project. The contribution of man-made chemicals in produced water to the total hazard of offshore oil and gas is difficult to determine as it may vary for each location, which is recognized by the current scientific discussion on this topic. Because of the lack of information on man-made chemicals, the assessment of emissions of hazardous substances from the offshore oil and gas industry in this report is based on the natural occurring materials present in produced water.

Many of the substances emitted via produced water and corrosion protection are expected to be hazardous to the marine environment

From the 32 identified substances in produced water and from corrosion protection 24 substances were identified as being potentially hazardous to the marine environment. These 24 substances can be categorized as aromatic hydrocarbons, heavy metals and phenols. From these 24 substances 10 occur on the Substitute It Now list (SIN), 4 substances occur on the OSPAR list of priority action, 10 substances occur on the OSPAR list of possible concern, two substances are listed as endocrine disruptive and 15 substances are mentioned in either Annex 6 or 8 of the German OGewV (OGewV, 2016), the national implementation of the priority substances of the Water Framework Directive (EU-Directive 2013/39/EU). 5 out of 32 substances are even classified as persistant, bioaccumulative and toxic (PBT) substances, namely fluoranthene, benzo[a]anthracene, chrysene and 4-ter-octylphenol. Concluding, many of the substances emitted via produced water and corrosion protection are expected to be hazardous to the marine environment and all aquatic organisms.

To limit the emissions of hazardous substances, substitute assessments or alternative technologies for the individual processes should be performed frequently. To get a better understanding of possibly emitted man-made chemicals, more detailed information on the available product lists from local authorities would be necessary. In the case, that operational materials contain hazardous substances, the free emission into the water should be prevented or at least reduced. In this context, especially substances with PBT criteria should be prevented from entering the marine environment.

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A Appendix

A.1 List of substances identified in Produced water, including their calculated loads

- Column A displays the average concentration per oil platforms (n=21), monitored in 2010.
- Column B displays the average concentration per gas platforms (n=8), monitored in 2010.
- Column C displays the average concentration of the total set of all platforms.
- Column D displays the total load for 23 installations, based on the individual concentrations and individual flows, available for 23 installations.
- Column E displays the total load for the OSPAR region, based on the average concentrations (column C) and the total volume of Produced Water in the OSPAR region in 2010, namely 361133607 m^3.
- Column F displays the total load for the OSPAR region, based on the load of the 23 installations, and the total volume of Produced water in the OSPAR region. The volume of the 23 installations consists of 25% of the total volume of Produced water in the OSPAR region
-

Substance	A	B	C	D	E	F
	average oil platforms (µg/l)	average gas platforms (µg/l)	average total (mg/m3)	total load for 23 installations (mg)	total load based on average (ton/year)	total load based on 23 installations (ton/year)
volume (m3/Y)				90977931	361133607,00	
Total Hydrocarbons	79,52	104,13	82,8	1745615914	29903,07	6929,16
Benzene	8775,45	43,3	17,11	870518117,6	6178,82	3455,49
Dispersed oil (C7-C40)	13,06	21,06	17,06	535204193,6	6161,66	2124,47
Toluene	5,56	20,46	9,16	581117236,8	3306,36	2306,72
Zinc	4959,34	9341,89	6017,2	61872470974	2173,01	245,6
Phenol	3239,44	4284	3612,5	1.02E+11	1304,6	403,16
Dispersed oil (C10-C40)	3,38		3,38	0	1218,83	0
Sum C1-C3 phenols	2642,68	2993,39	2727,33	2.29E+11	984,93	909,7
Xylenes	1,36	6,73	2,65	138273392,9	958,12	548,87
Ethylbenzene	0,72	0,78	0,73	65984735,94	264,15	261,92

Substance	A	B	C	D	E	F
	average oil platforms (µg/l)	average gas platforms (µg/l)	average total (mg/m3)	total load for 23 installations (mg)	total load based on average (ton/year)	total load based on 23 installations (ton/year)
Lead	558,05	1273,34	730,71	9309904239	263,88	36,96
NPD	1086,38	0	668,54	38450958300	241,43	152,63
C3-naphtalenes	393	676,51	427,02	33564267479	154,21	133,23
Dispersed oil (C7-C10)	0,42		0,42	0	151,68	0
C2-naphtalenes	354,16	650,38	389,71	24711219901	140,74	98,09
1-methylnaphtalene	380,84	75,76	327	16618460450	118,09	65,97
C1-naphtalenes	350,78	50,74	324,69	43384876131	117,26	172,21
Naphtalene	348,38	55,66	277,72	37082170309	100,29	147,2
2-methylnaphtalene	290,67	36,73	245,86	15823204226	88,79	62,81
Sum C4-C5 phenols	163,88	14,51	127,82	9564559096	46,16	37,97
C1-phenanthrenes	90,59	219,07	101,76	5106554597	36,75	20,27
C2-phenanthrenes	66,73	72	67,19	6015025009	24,27	23,88
C3-phenanthrenes	57,89	27,5	55,25	4344960290	19,95	17,25
Sum C6-C9 Phenols	60,06	1,11	45,83	805970480,9	16,55	3,2
Arsenic	42,28	15,97	35,93	420452720	12,97	1,67
C2-dibenzothiophenes	28,5	11,5	27,02	2888308081	9,76	11,47
C3-dibenzothiophenes	27,95	11,5	26,52	2384310669	9,58	9,46
Phenanthrene	26,27	24,38	25,81	1978055349	9,32	7,85
Dipenzothiophene	15,32	70,47	21,94	890494006,4	7,92	3,53

Substance	A	B	C	D	E	F
	average oil platforms (µg/l)	average gas platforms (µg/l)	average total (mg/m3)	total load for 23 installations (mg)	total load based on average (ton/year)	total load based on 23 installations (ton/year)
Chromium	13,92	41,2	20,5	187315340,3	7,4	0,74
Phenanthrene/anthracene	17,2		17,2	0	6,21	0
Acenaphtylene/acenaphtene	14,4		14,4	0	5,2	0
Cadmium	12,14	20,95	14,26	167002092,2	5,15	0,66
C1-dibenzothiophenes	14,96	5,16	14,11	1629792670	5,1	6,47
Mercury	16,63	2,54	13,23	3951436261	4,78	15,69
Fluorene	15,45	3	12,44	1836614222	4,49	7,29
Copper	6,46	14,26	8,34	51361993,41	3,01	0,2
Nickel	3,42	14,51	6,1	62647538,5	2,2	0,25
Acenaphtene	3,66	0,16	2,68	230812058,4	0,97	0,92
B(a)a/chrysene/triphenylene	0,94		0,94	0	0,34	0
Acenaphthylene	1,21	0,1	0,9	82988351,64	0,32	0,33
Chrysene	0,98	0,49	0,84	82987244,8	0,3	0,33
Pyrene	0,81	0,31	0,69	58884571,38	0,25	0,23
Fluoranthene	0,56	0,04	0,43	29577564,59	0,16	0,12
Anthracene	0,43	0,19	0,36	46442877,74	0,13	0,18
Benzo(a)anthracene	0,27	0,11	0,22	21303832,18	0,08	0,08
Benzo(b)fluorantene	0,23	0,04	0,18	16847414,94	0,07	0,07

Substance	A	B	C	D	E	F
	average oil platforms (µg/l)	average gas platforms (µg/l)	average total (mg/m3)	total load for 23 installations (mg)	total load based on average (ton/year)	total load based on 23 installations (ton/year)
B(a+e)p/perylene	0,12	0	0,11	0	0,04	0
Benzo(a)pyrene	0,06	0,01	0,05	4155788,64	0,02	0,02
B(ghi)p	0,08	0	0,06	5283637,4	0,02	0,02
Benoz(k)fluorantene	0,03	0	0,02	2661516,66	0,01	0,01
Dibenz(a,h)anthracene	0,02	0	0,02	2250247,22	0,01	0,01
Indenol(123cd)pyrene	0,02	0	0,01	1635776,49	0,01	0,01

A.2 Annex PBT criteria of identified substances

CAS nr	Substance	Category	PBT	Persistancy (short)	Bioaccumulation (short)	Toxicity (short)	Toxicity (PNEC value in µg/l)	GHS class	H-phrases	Sin-List	OSPAR list of possible concern	Endocrine disruptive ECHA	OGewV	OSPAR chemicals of priority action
71-43-2	benzene	Shortlisted	No	readily biodegradable	no potential for bioaccumulation		8	GHS02 GHS08 GHS07	H225 H304 H315 H319 H340 H350 H372 H412	Flam. Liq. 2 Carc. 1A Muta. 1B STOT RE 1 Asp. Tox. 1 Eye Irrit. 2 Skin Irrit. 2	#N/A	#N/A	OGewV - Anlage 8	#N/A
108-88-3	toluene	Shortlisted	No	readily biodegradable	no potential for bioaccumulation		7.4	GHS02 GHS07 GHS08	H225 H304 H315 H336 H361 H361d H373 H412	#N/A	#N/A	#N/A	#N/A	#N/A
100-41-4	ethylbenzene		No	readily biodegradable	no potential for bioaccumulation		10	GHS02 GHS07 GHS08	H225 H332 H350 H340 H373	#N/A	#N/A	#N/A	#N/A	#N/A
91-20-3	Napthalene	Shortlisted	No	easily/inherently degradable	no potential for bioaccumulation		2	GHS07 GHS08 GHS09	H302 H351 H410	Carc. 2 Acute Tox. 4 * Aquatic Acute 1 Aquatic Chronic 1	#N/A	#N/A	OGewV - Anlage 8	#N/A
83-32-9	Acenaphthene	Shortlisted	information available at ECHA	No information available at ECHA	No information available at ECHA		0.38	GHS09	H410	#N/A	A	#N/A	#N/A	#N/A

CAS nr	Substance	Category	PBT	Persistancy (short)	Bioaccumulation (short)	Toxicity (short)	Toxicity (PNEC value in µg/l)	GHS class	H-phrases	Sin-List	OSPAR list of possible concern	Endocrine disruptive ECHA	OGewV	OSPAR chemicals of priority action
208-96-8	Acenaphthylene		information available at ECHA	No information available at ECHA	No information available at ECHA		0.13			#N/A	#N/A	#N/A	#N/A	#N/A
86-73-7	Fluorene	Shortlisted	information available at ECHA	No information available at ECHA	No information available at ECHA		0.25	GHS09	H410	#N/A	#N/A	#N/A	#N/A	#N/A
120-12-7	Anthracene	Shortlisted	Possibly, according to reference 2	inherently biodegradable	BCF=1900		0.1	GHS07 GHS09	H315 H410	#N/A	A	#N/A	OGewV - Anlage 8	#N/A
85-01-8	Phenanthrene	Shortlisted	Possibly, according to reference 2	No information available at ECHA	No information available at ECHA		1.3	GHS07 GHS09	H302 H400 H410	#N/A	#N/A	#N/A	OGewV - Anlage 6	#N/A
206-44-0	Fluoranthene	Shortlisted	yes	No information available at ECHA	No information available at ECHA		0.0063	GHS07 GHS09	H302 H319 H400 H410	#N/A	A	#N/A	OGewV - Anlage 8	#N/A
129-00-0	Pyrene	Shortlisted	No information available at	No information available at ECHA	No information available at ECHA		0.023	GHS09	H410	#N/A	A	#N/A	#N/A	#N/A
56-55-3	Benz[a]anthracene	Shortlisted	Yes	No information available at ECHA	No information available at ECHA		0.0012	GHS09 GHS08	H350 H400 H410	Aquatic Acute 1 Aquatic	A	#N/A	#N/A	#N/A
218-01-9	Chrysene	Shortlisted	Yes	No information available at ECHA	No information available at ECHA		0.007	GHS08 GHS09	H350 H400 H410	Muta. 2 Aquatic Acute 1	A	#N/A	#N/A	#N/A
53-70-3	Dibenzo[a,h]anthracene	Shortlisted	No	No information available at ECHA	No information available at ECHA		0.00014	GHS08 GHS09	H350 H400 H410	Aquatic Acute 1 Aquatic	A	#N/A	#N/A	#N/A

CAS nr	Substance	Category	PBT	Persistancy (short)	Bioaccumulation (short)	Toxicity (short)	Toxicity (PNEC value in µg/l)	GHS class	H-phrases	Sin-List	OSPAR list of possible concern	Endocrine disruptive ECHA	OGewV	OSPAR chemicals of priority action
50-32-8	Benzo[a]pyrene	Shortlisted	No	No information available at ECHA	No information available at ECHA		0.00017	GHS09 GHS08 GHS07	H340 H350 H400	Muta. 1B Repr. 1B Skin Sens. 1	A	#N/A	OGewV - Anlage 8	#N/A
N/A	Dispersed oil			No information available at ECHA			70.5			#N/A	#N/A	#N/A	#N/A	#N/A
7440-38-2	Arsenic	Shortlisted	PBT assessment does not apply.	N/A	N/A		0.6 +Cb	GHS06 GHS08 GHS09	H301 H331 H350 H410	#N/A	#N/A	#N/A	OGewV - Anlage 6	#N/A
7440-43-9	Cadmium	Shortlisted	PBT assessment does not apply.	N/A	N/A		0.2+Cb	GHS06 GHS08 GHS09	H350 H341 H361 H361fd H330 H372 H400 H410	Pyr. Sol. 1 Carc. 1B Muta. 2 Repr. 2 Acute Tox. 2 * STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	#N/A	#N/A	OGewV - Anlage 8	A
7440-47-3	Chromium		PBT assessment does not apply.	N/A	N/A		0,6+Cb		No signal word	#N/A	#N/A	#N/A	OGewV - Anlage 6	#N/A
7440-50-8	Copper		PBT assessment does not apply.	N/A	N/A		2.6		No signal word	#N/A	#N/A	#N/A	#N/A	#N/A
7440-02-0	Nickel	Shortlisted	PBT assessment does not apply.	N/A	N/A		8.6 +Cb	GHS08 GHS07	H351 H372 H317 H412	#N/A	#N/A	#N/A	OGewV - Anlage 8	#N/A

CAS nr	Substance	Category	PBT	Persistancy (short)	Bioaccumulation (short)	Toxicity (short)	Toxicity (PNEC value in µg/l)	GHS class	H-phrases	Sin-List	OSPAR list of possible concern	Endocrine disruptive ECHA	OGewV	OSPAR chemicals of priority action
98-54-4	4-tert-butylphenol	Shortlisted	No	readily biodegradable	low bioaccumulation potential		0.64	GHS05 GHS08 GHS09	H315 H318 H361 H361f H410	Repr. 2 Skin Irrit. 2 Eye Dam. 1	B	Concluded	#N/A	#N/A
80-46-6	4-tert-pentylphenol	Shortlisted	No	inherently bioegradable	low bioaccumulation potential		0.2	GHS05 GHS07 GHS09	H314 H317 H410	#N/A	#N/A	Concluded	#N/A	#N/A
140-66-9	4-tert-octylphenol	Shortlisted	yes	inherently biodegradable,	BCF of 758		0.01	GHS05 GHS09	H315 H318 H410	Skin Irrit. 2 Eye Dam. 1 Aquatic Acute 1 Aquatic Chronic 1	#N/A	#N/A	#N/A	A
2515-52-3	Nonylphenol (C9 alkyl phenols representative)	Shortlisted	No	No information available at ECHA	low bioaccumulation potential, BCF of <2000		0.3	GHS09 GHS08 GHS05 GHS07	H302 H314 H400 H410	#N/A	A	#N/A	#N/A	#N/A
1330-20-7	Xylene		No	ready biodegradable				GHS02 GHS07 GHS08	H226 H312 H332 H315	#N/A	#N/A	#N/A	#N/A	#N/A
205-99-2	Benzo[b]fluoranthene	Shortlisted	No	No information available at ECHA	No information available at ECHA			GHS08 GHS09	#N/A	Carc. 1B Aquatic Acute 1 Aquatic Chronic 1	#N/A	#N/A	OGewV - Anlage 8	#N/A
191-24-2	Benzo[ghi]perylene	Shortlisted	yes	No information available at ECHA	No information available at ECHA				#N/A	#N/A	A	#N/A	OGewV - Anlage 8	#N/A

Legend of the table	
	Hazardous substance
	Possibly hazardous substance
	Expected to be possibly hazardous
	Other identified substances
Red font color	Missing data
Explanation of colours	
PBT	Persistant, Bioaccumulative and Toxic
PB/PT	Persistant and Bioaccumulative/Persistant and Toxic
H400	H400
H410	H410
H411	H411: Toxic to aquatic life with long lasting effects.
H412	H412
H413	H413: May cause long lasting harmful effects to aquatic life.
Aquatic Acute 1	Very toxic to aquatic life according to the SIN-list
Aquatic Chronic 1	Very toxic to aquatic life with long lasting effects according to the SIN-list
Endocrine Disruptor (ER)	Endocrine Disruptor according to ECHA
Expected to be toxic	Not classified, but expected to be toxic to aquatic life.
H300	H300: Fatal if swallowed.
H301	H301: Toxic if swallowed.
H302	H302: Harmful if swallowed.
H304	H304
H310	H310: Fatal in contact with skin.
H311	H311: Toxic in contact with skin.
H312	H312: Harmful in contact with skin.
H340	H340
H341	H341: Suspected of causing genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H350	H350
H351	H351: Suspected of causing cancer <state route of exposure if it is conclusively proven that no other routs of exposure cause the hazard>.
H360	H360: May damage fertility or the unborn child <state specific effect if known > <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H361	H361: Suspected of damaging fertility or the unborn child
H370	H370: Causes damage to organs.
H371	H371: May cause damage to organs.
H372	H372
H373	H373: May cause damage to organs <or state all organs affected, if known> through prolonged or repeated exposure <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
Possibly ED	Currently ED assessment is under development by ECHA.

Carc. 1B	May cause cancer
Muta. 1B	May cause genetic defects
Asp. Tox. 1	May be fatal if swallowed and enters airways
Press. Gas	
Flam. Gas 1	Extremely flammable gas
Carc. 2	Suspected of causing cancer
Acute Tox. 4 *	Harmful if swallowed/Harmfull in contact with skin/Harmfull if inhaled
Skin Corr. 1B	Causes severe skin burns and eye damage
Repr. 2	Suspected of damaging fertility. Suspected of damaging the unborn child
Aquatic Acute 1	Very toxic to aquatic life
Aquatic Chronic 1	Very toxic to aquatic life with long lasting effects
Pyr. Sol. 1	Catches fire spontaneously if exposed to air
Acute Tox. 2 *	Fatal if swallowed/fatal in contact with skin/fatall if inhaled
Muta. 2	Suspected of causing genetic defects

Categories in OSPAR list of possible concern:

- Section A details substances which warrant further work by OSPAR because they do not meet the criteria for Sections B – D and substances for which, for the time being, information is insufficient to group them in Sections B – D
- Section B contains substances which are of concern for OSPAR but which are adequately addressed by EC initiatives or other international forums
- Section C contains substances which are not produced and/or used in the OSPAR catchment or are used in sufficiently contained systems making a threat to the marine environment unlikely
- Section D lists substances which appear not to be "hazardous substances" in the meaning of the Hazardous Substances Strategy but where the evidence is not conclusive

Categories in OSPAR list of priority action:

A: CHEMICALS WHERE A BACKGROUND DOCUMENT HAS BEEN OR IS BEING PREPARED

B: CHEMICALS WHERE NO BACKGROUND DOCUMENT IS BEING PREPARED BECAUSE THEY ARE INTERMEDIATES IN CLOSED SYSTEMS

C: CHEMICALS WHERE NO BACKGROUND DOCUMENT IS BEING PREPARED BECAUSE THERE IS NO CURRENT PRODUCTION OR USE INTEREST

B Comparison of selected hydrocarbon and metal concentrations at different cuttings piles

Component	Units	Cuttings Pile									Background			
		Murchison Cuttings Pile, July 2011 (push cores)	*Murchison Surface Sediments July 2011*	North Cormorant Cuttings Pile, July 2011	Beryl A Cuttings Pile (Station B1) (Breuer *et al.*, 2008)	Cuttings Review[1] (Cordah/Rogal and Research, 1999)	Cuttings Review[2] (Cordah, 2000)	NW Hutton (BMT Cordah, 2004)	Miller (Aquatera, 2007)	Ekofisk 2/4A (DNV, 2009)	East Shetland Basin Background[3]	Background Conc. (BC)	Background Assessment Conc. (BAC)	Effect Range Low (ERL)
THC	%	0.16 to 1.0	*0.0001 to 0.045*	0.3 to 13.3	-	0 to 14.3	0 to 37.9	4.9	1.8 to 7.7	4.7[b]	0.0005 to 0.0015	-	-	-
Total PAH	$\mu g\ g^{-1}$	14.1 to 65.8	*0.028 to 2.41*	11 to 302	134 to 472	0 to 1,282	-	773[b]	-	-	-	0.19	0.36	3.34
PCB	$ng\ g^{-1}$	0.44 to 0.99	*<0.10 to 0.56*	-	-	-	-	-	-	-	-	0.20	0.46	11.50
APE	$\mu g\ g^{-1}$	574 to 1,690	*4.1 to 784*	-	-	-	-	-	-	-	-	-	-	-
TBT	$ng\ g^{-1}$	1.7 to 5.0	*<0.4 to 2.5*	-	-	-	-	-	-	-	-	-	-	-
Total Barium (TBa)	$\mu g\ g^{-1}$	173,000 to 231,000	*<500 to 64,000*	7,500 to 216,000	228,557	202 to 231,000	-	101,000	-	-	500 to 1,000	-	-	-
Chromium (Cr)	$\mu g\ g^{-1}$	36 to 41.7	*5.56 to 65.3*	42 to 59[a]	426	-	12 to 101	87	27 to 56	-	5 to 10	60	81	81
Lead (Pb)	$\mu g\ g^{-1}$	279 to 3,043	*3.05 to 447*	82 to 296[a]	689	7 to 361	-	170	12 to 172	75[c]	5 to 15	25	38	47
Arsenic (As)	$\mu g\ g^{-1}$	10.1 to 24.6	*1.42 to 22.5*	14 to 29[a]	-	2.9 to 2.8	-	-	7 to 15	-	-	15	25	-
Cadmium (Cd)	$\mu g\ g^{-1}$	0.99 to 5.74	*<0.03 to 1.58*	1.7 to 8.8[a]	-	0.1 to 8.0	<1 to 25	1.5	0.2 to 1.5	0.5[c]	0.05 to 0.1	0.20	0.31	1.20
Mercury (Hg)	$\mu g\ g^{-1}$	1.73 to 3.89	*<0.03 to 2.33*	0.61 to 1.57[a]	-	0.1 to 32.6	0.01 to 1.52	-	0.03 to 2.25	0.16[c]	0.01 to 0.05	0.05	0.07	0.15
Aluminium (Al)	$\mu g\ g^{-1}$	12,030 to 18,890	*1,450 to 10,700*	23,200 to 31,200[a]	-	-	-	-	-	-	-	-	-	-
Copper (Cu)	$\mu g\ g^{-1}$	59.8 to 237	*1.85 to 146*	58.2 to 81.7[a]	281	-	-	-	-	-	-	20.0	27.0	34.0
Iron (Fe)	$\mu g\ g^{-1}$	26,580 to 41,440	*3,830 to 25,100*	24,800 to 37,000[a]	-	-	-	-	-	-	-	-	-	-
Lithium (Li)	$\mu g\ g^{-1}$	-	-	29.3 to 80.1[a]	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	$\mu g\ g^{-1}$	397 to 860	*39.9 to 278*	466 to 1,370[a]	-	-	-	-	-	-	-	-	-	-
Nickel (Ni)	$\mu g\ g^{-1}$	24.6 to 50.4	*2.85 to 25.2*	33.4 to 42.1[a]	-	-	-	-	-	-	-	30	36	-
Strontium (Sr)	$\mu g\ g^{-1}$	221 to 2,018	*72.1 to 820*	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	$\mu g\ g^{-1}$	33.6 to 44.4	*4.90 to 61.2*	64.8 to 105[a]	523	-	-	-	-	-	-	-	-	-
Tin (Sn)	$\mu g\ g^{-1}$	-	-	1.73 to 3.33[a]	-	-	-	-	-	-	-	-	-	-
Zinc (Zn)	$\mu g\ g^{-1}$	523 to 753	*5.77 to 628*	658 to 3,410a	-	-	-	-	-	-	-	90	122	150

[1]range of data obtained from a review of 10 different cuttings piles. [2]range of data obtained from a review of 15 different cuttings piles. [3]estimated from various surveys in East Shetland Basin, data obtained from UKOOA benthic database (UKOOA, 2000). [a]data from the uppermost core sections [b]total NPD [c]average concentration.

Source: Genesis, 2016.

* THC: Total Hydrocarbons

** PAH: Polycyclic Aromatic Hydrocarbons

*** PCB: Polychlorinated biphenylethers

**** APE: Alkylphenolethoxylates

***** TBT: Tributyltin