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Final report

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

Part 1: Emissions from offshore wind 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 – Work package 1: Emissions from offshore wind industry

Within the RESOW project (Reduction of impacts of hazardous substances during installation and operation of offshore wind farms), potential emissions from the offshore industry into the North and Baltic Seas are investigated. This work package gives an overview of possible emission sources from the offshore wind industry associated with the different life phases of offshore wind structures such as installation, operation and decommissioning. Possible emission sources including offshore wind turbines, substations, converter platforms and cables are investigated by means of literature studies and interviews. In a first step, operational materials are identified, which are mostly mixtures composed of various individual substances and are required for smooth operation of technical installations or maintenance of the offshore structures. Furthermore, emission sources from open systems, corrosion protection measures, scour protection as well as other offshore infrastructure and installation and decommissioning techniques are investigated. In the following step, the associated hazardous substances of the relevant materials are analysed, and a substance list is developed. The individual substances are further investigated regarding their hazardous properties and their impact on the marine environment in particular. The assessment of the hazardous properties is based on PBT criteria, H-phrases related to aquatic toxicity, the SIN (Substitute It Now!) list, the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) list of substances of very high concern (SVHC), the OSPAR list of substances of possible concern, the OSPAR list of substances that pose little or no risk to the environment (PLONOR), the ECHA (European Chemicals Agency) list of endocrine disrupting substances, the substances in the German Ordinance on the Protection of Surface Waters (Annex 6 and Annex 8) and the OSPAR List of Chemicals for Priority Action. The analysis shows the highest emissions into water are caused by materials applied in open systems such as the release of metals from galvanic corrosion protection measures. Furthermore, AFFF foams, fuels and outdoor applied hydraulic oils are found to be a possible emission source since they have an increased risk of being emitted into the marine environment as a result of an accident.

Kurzbeschreibung: Überblick über mögliche Emissionen von gefährlichen Stoffen aus der Offshore-Industrie in die Meeresumwelt – Arbeitspaket 1: Emission aus der Offshore-Wind-Industrie

Im Rahmen des RESOW Projekts (Reduzierung von Schadstoffwirkungen bei Bau und Betrieb von Offshore-Windenergieanlagen, Umspann- und Konverterplattformen und Seekabeln) werden Einträge aus Offshore Industrie Quellen in die Meeresumwelt von Nord- und Ostsee betrachtet. Es wird zwischen Quellen aus der Offshore Öl- und Gas Industrie sowie der Offshore Wind Industrie differenziert. Ziel des Arbeitspakets 1 ist eine Übersicht der Schadstoffe aus der Offshore Wind Industrie zu erstellen die bei Installation, Betrieb und Rückbau der Offshore-Strukturen in die Meeresumwelt gelangen können. Die betrachteten Offshore Strukturen in der Wind-Industrie umfassen die Offshore-Windenergieanlagen, Umspannwerke, Konverterplattformen und Kabel. In einem ersten Schritt wurden die für den Betrieb relevanten Betriebsstoffe identifiziert und in einer detaillierten Liste zusammengefasst. Betriebsmittel sind dabei meist Mixturen aus verschiedenen individuellen Substanzen, die für den reibungslosen Betrieb von technischen Anlagen oder für Wartungsarbeiten auf den Offshore Bauwerken benötigt werden. Weiterhin wurden weitere mögliche Quellen aus offenen Kreisläufen, Korrosionsschutzmaßnahmen, Kolkschutzmaßnahmen, sowie aus Installations- oder Rückbauverfahren betrachtet. Basierend auf der Betriebsstoffliste sowie den Erkenntnissen aus weiteren Offshorequellen wurde eine Stoffliste angefertigt, die die Inhaltsstoffe der Betriebsmittel oder Stoffe aus anderen Einträgen enthält. Die Stoffe wurden weiterhin auf ihre mögliche Gefahr für die aquatische Umwelt untersucht. Die Beurteilung der möglichen Gefahr

erfolgt anhand von PBT Kriterien, H-Sätzen zur aquatischen Toxizität beinhalten, der SIN Liste (Substitute It Now!), der REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) Liste für besonders besorgniserregender Stoffe (Substances of Very High Concern, SVHC) Liste, der OSPAR Liste für möglicherweise bedenkliche Substanzen, der OSPAR Liste der Substanzen mit wenig oder keiner Gefahr für die Umwelt (PLONOR) oder der ECHA (European Chemical Agency) Liste für endokrin schädliche Substanzen. Die Untersuchung zeigt, dass Materialien die in offenen Systemen Anwendung finden für die größten Emissionen in die Meeresumwelt verantwortlich sind, wie zum Beispiel galvanischen Korrosionsschutzmaßnahmen die Metalle freisetzen. Weiterhin stellen AFFF Schäume, Kraftstoffe und extern angewandte Hydrauliköle mögliche Emissionsquellen dar, da sie ein erhöhtes Risiko besitzen durch einen Unfall in die Meeresumwelt zu gelangen.

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AC	Alternating current
AFFF	Aqueous Film Forming Foam
AwSV	Ordinance on Facilities Handling Substances that are Hazardous to Water (Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen)
BAT	Best available technique
BSH	German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie)
CAS	Chemical Abstracts Service
ChemSec	International Chemical Secretariat
CO_2	Carbon dioxide
DC	Direct current
ECHA	European Chemicals Agency
EEZ	Exclusive economic zone
EIA	Environmental Impact Assessment
EP	Epoxy
FEP	Site development plan (Flächenentwicklungsplan)
GACP	Galvanic cathodic protection
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GSC	Geotextile sand containers
HDD	Horizontal Directional Drilling
HV	High voltage
ICCP	Impressed current cathodic protection
IMO	International maritime organisation
MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MM	Maintenance materials
MP	Monopile
MSDS	Material safety data sheets
MV	Medium voltage
n.d.	no date
OCP	Offshore converter plattform
OM	Operational materials
OSPAR	Oslo and Paris Conventions
OSS	Offshore substation
OWF	Offshore wind-farm
OWT	Offshore wind-turbine
PBT	Persistent, bioaccumulative and toxic
PE	Polyethylene
PFAS	Per- and polyfluoroalkyl substances

PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PLONOR	(Substances, which) Pose little or no risk to the environment
PMG	Permanent magnet generator
PP	Polypropylene
ppm	parts per million (10^{-6})
PTN	Power to net
PUR	Polyurethane
PVC	Polyvinylchloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RESOW	Reduction of impacts of hazardous substances during installation and operation of offshore windfarms
SCFF	Self-contained, fluid filled (cables)
SCGF	Self-contained, gas filled (cables)
SIN	Substitute it now
SVHC	Substance of very high concern
TP	Transition piece
TSS	Total suspended solids
UBA	German Environment Agency (Umweltbundesamt)

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We are also very grateful to Dr. Anita Künitzer, Ulrike Pirntke and Hans-Peter Damian from the Umweltbundesamt (UBA) for their continuous guidance during the implementation of this analysis, the numerous discussions, meetings and checks of chapters and drafts of this report, as well as the advice by further experts from the Umweltbundesamt.

Summary

The offshore wind industry is a relatively young industry, but the market has been growing significantly in the last years. This trend is expected to continue due to the EU strategy goal to increase Europe's offshore wind capacity to at least 60 GW in 2030 and 300 GW in 2050. Knowing about this trend, it is important to be aware of the impact of the fast-growing offshore wind energy industry on the environment. To date, the environmental impact of the offshore wind industry regarding chemical emissions into the aquatic environment has not been assessed comprehensively. In contrast, steps have been initiated to quantify and minimise emissions from the long existing offshore oil and gas industry by the OSPAR Offshore Industries Committee. The aim of this research project named "Reduction of impacts of hazardous substances during installation and operation of offshore wind farms" (RESOW) is to provide an overview of possible substance emissions from the offshore industry. In doing so, possible substance emission sources can be assigned to certain offshore structures during the lifecycles of the structures such as installation, operation and decommissioning. Furthermore, the emission sources should be quantified to give an overview of the emissions from the offshore industries and of other maritime industries such as maritime transport.

In this work package, specifically possible emissions of hazardous substances from the offshore wind industry have been investigated. To this end, emission studies and waste and operational materials strategies of various German wind farms in the North and Baltic Seas have been analysed. Further, experts from UBA, BSH and Deltares as well as external experts have been consulted. In addition, a workshop with internal and external experts has been organised to discuss the investigation approach as well as the results of the analysis.

The investigations in this study aim to identify possible emissions of hazardous substances associated with the installation, operation and decommissioning of offshore wind energy structures such as wind turbines, substations, converter platforms and cables. The emission sources during the installation phase are mostly related to the processes involved to secure the individual structures into place (such as pile driving, trenching, etc.). The possible emissions during operation are related to the operational materials which are mostly composed of various individual substances and are required while operating technical installations or for maintenance of the offshore structures. The emissions to the aquatic environment occur due to accidental spilling as a result of human error or material failure, intentional emissions (due to e.g. cooling circuits and antifouling measures) or the emissions are related to corrosion protection measures at the structures. Emissions from decommissioning are predominantly related to operations involved in the deconstruction process or the estimated effects (release of substances) due to the structure parts remaining in the environment for a long time.

To get insights into the materials present on offshore structures, an overview of operational materials has been compiled. The overview includes the type of material, its application, the location of its application and the stored amounts. Further, a distinction is made for materials between their application as an operational material or maintenance material and their application in open systems, in closed systems with low chance of release and in closed systems with a higher chance of release. Based on the operational material lists, the associated potential hazardous substances are determined and investigated. The hazardous substances are evaluated specifically for their hazardous properties for the aquatic environment. The assessment of the hazardous properties is based on PBT criteria, H-phrases related to aquatic toxicity, the SIN list, the REACH list of substances of very high concern (SVHC), the OSPAR List of Substances of Possible Concern, the OSPAR list of substances that pose little or no risk to the environment (PLONOR), the ECHA list of endocrine disrupting substances, the substances in the German

Ordinance on the Protection of Surface Waters (Annex 6 and Annex 8) and the OSPAR List of Chemicals for Priority Action. Based on the assessment, the substances evaluated as hazardous were investigated further for their amounts that are present and their risk of emission into the marine environment. Application of substances in open systems cause direct emissions into the environment and, thus, represent the predominant source of emission from the offshore wind industry. In open systems, the emissions from galvanic cathodic protection systems lead to a constant release of metals into the marine environment. Hazardous substances assigned with closed systems with a higher risk of emissions are fluorinated surfactants present in AFFF (Aqueous Film Forming Foam) firefighting foams, applied in an emergency at the helicopter deck of offshore substations, and fuels (e.g. diesel), which are delivered to the offshore substation (OSS) or offshore converter platform (OCP) structures in high volumes by bunkering, which bears a higher risk for accidents, for example due to human error. Further, grease and gear oils used on outdoor technical installations of offshore wind structures (e.g. cranes) also belong to this category. In total, 89 hazardous substances have been identified which are applied in closed systems. However, unless there is an accident or human error, these substances should not be emitted into the water.

The investigation showed that currently no specific technical guideline applies in the German exclusive economic zone (EEZ) regarding the application and use of substances which are hazardous to the aquatic environment. Although, a regulation on the application and use of substances which are hazardous to the aquatic environment exists for the application onshore and within coastal waters (12 nautical miles), it is not applicable by law in the exclusive economic zone (EEZ) where most offshore wind installations are being built. A few general technical requirements to minimise emissions as much as possible are provided in the site development plan (BSH, 2020). However, structural and operational security measures still need to be ensured on an individual basis.

It is expected that regulations on best practice for structural measures to avoid the emission of hazardous substances on offshore wind structures can limit the risk of accidental release. Further, the identified link between human error and emissions from closed systems emphasizes the importance of strict routines, safety protocols and experienced personnel for the maintenance procedure on offshore structures.

The study further revealed the difficulty to investigate hazardous components in operational materials. Often there is no open information on components of operational materials available in e.g. material safety data sheets (MSDS). Improved availability of information provided by the manufacturers can enable a more informed handling of materials, allowing for a broader and easier search for substitutes and awareness-raising about risks.

Zusammenfassung

Obwohl der Offshore Windindustrie-Markt relativ jung ist, hat er sich in den letzten Jahren stark entwickelt und ist stetig gewachsen. Auch zukünftig wird dem Markt Wachstum prognostiziert, da im Rahmen der EU-Strategie ein Ausbau von Europas Offshore Wind Kapazität zu 60 GW in 2030 und 300 GW in 2050 vorgesehen ist. Mit dieser Entwicklung vor Augen ist es wichtig, sich über den Einfluss einer schnell wachsenden Offshore Windindustrie auf die Umwelt bewusst zu werden. Bis heute wurde keine ausführliche Analyse des Einflusses von Stoffemissionen aus der Offshore Windenergie auf die maritime Umwelt durchgeführt. Im Gegensatz dazu hat das OSPAR Offshore Industrie Komitee bereits Schritte zur Quantifizierung und Minimierung von Emissionen aus der Offshore Öl- und Gasindustrie eingeleitet. Das Forschungsvorhaben RESOW (Reduzierung von Schadstoffwirkungen bei Bau und Betrieb von Offshore-Windenergieanlagen, Umspann- und Konverterplattformen und Seekabeln) soll eine Übersicht über die möglichen Stoffemissionen aus der Offshore-Industrie geben. Weiterhin sollen die Emissionen der Offshore Industrie anderen Industrien wie der kommerziellen Schifffahrt gegenübergestellt werden.

In diesem Arbeitspaket werden die möglichen Emissionen von Gefahrenstoffen aus der Offshore Windindustrie analysiert. Dafür wurden vertrauliche Emissionsstudien und Abfall- und Betriebsstoffkonzepte von verschiedenen deutschen Windparks in der Nord- und Ostsee untersucht. Dazu wurden weiterhin Experten des Umweltbundesamts (UBA), des Bundesamts für Seeschifffahrt und Hydrografie (BSH) und des Forschungsinstituts Deltares sowie externe Experten in die Studie involviert. Im Rahmen eines Workshops wurden der Untersuchungsansatz der Studie sowie die Ergebnisse internen und externen Experten präsentiert und kritisch diskutiert.

In dieser Studie werden die möglichen Emissionen von gefährlichen Stoffen aus der Offshore Windindustrie je nach der Lebensphase des Bauwerks, also Installation, Betrieb und Rückbau, sowie dem Bauwerkstyp selbst (Windturbinen (OWT), Umspannwerke (OSS), Transformerplattformen (OCP) und Kabeln) unterschieden. Die Emissionen, die während des Installationsvorgangs auftreten können, resultieren meist aus dem Installationsprozess zur Einbringung des jeweiligen Bauwerks, wie z.B. Pfahlrammung, Kabeleinbringung, etc.). Die möglichen Emissionen während des eigentlichen Betriebs stehen in Verbindung mit dem Einsatz von Betriebsmitteln, welche zumeist Gemische aus verschiedenen individuellen Stoffen sind und für den reibungslosen Ablauf der technischen Anlagen oder der Unterhaltung der Offshore Bauwerke benötigt werden. Im Betriebsablauf können Emissionen in Verbindung stehen mit kalkulierten Emissionen, wie z.B. infolge offener Kühlkreisläufe, Antifouling Maßnahmen oder Korrosionsschutzmaßnahmen, oder mit Unfällen infolge menschlichen oder baulichen Versagens. Emissionen infolge Rückbaus erfolgen meist aus dem Rückbauprozess oder infolge des langfristigen Verbleibs von Bauwerksteilen in der Meeresumwelt.

Um die Stoffe, die auf Offshore Bauwerken zum Einsatz kommen zu identifizieren, wurde zunächst ein Überblick über die vorhandenen Betriebsmittel erstellt. Der Überblick beinhaltet den Betriebsmitteltyp, die Anwendung, den Anwendungsort und die vorhandenen Mengen. Weiterhin werden die Betriebsmittel unterschieden in der Anwendung als operationelle Betriebsmittel oder Mittel für Unterhaltungsmaßnahmen. In Bezug auf den Anwendungsort wird untersucht, ob das Betriebsmittel in offenen Systemen, geschlossenen Systemen oder geschlossenen Systemen mit erhöhtem Unfallrisiko Anwendung findet. Basierend auf der resultierenden Betriebsstoffliste, werden potenzielle Gefahrenstoffe bestimmt und hinsichtlich ihres Gefahrenpotentials für die marine Umwelt untersucht. Die Beurteilung des Gefahrenpotentials erfolgt anhand von PBT Kriterien, H-Sätzen zur aquatischen Toxizität, der SIN Liste, der REACH SVHC Liste, der OSPAR Liste für möglicherweise bedenkliche Substanzen,

der OSPAR Liste der Substanzen mit wenig oder keiner Gefahr für die Umwelt (PLONOR), der ECHA Liste für endokrin schädliche Substanzen, dem Anhang 6 und 8 der Oberflächengewässerverordnung und der OSPAR-Liste der vorrangig zu behandelnden Chemikalien.

Die identifizierten Gefahrenstoffe für die marine Umwelt, wurden weiterhin bezüglich ihrer vorhandenen Mengen und des Risikos zur Emission in die marine Umwelt bewertet. Die Anwendung von Stoffen in offenen Systemen verursachen direkte Emissionen in die Umwelt und repräsentieren daher die maßgeblichste Emissionsquelle der Offshore Wind Industrie. Maßgebliche Emissionen in offenen Systemen verursacht die Anwendung von galvanischen Kathodenschutzsystemen, die zu einem konstanten Eintrag von Metallen führen.

Gefahrenstoffe, die geschlossenen Systemen mit einem erhöhten Unfallrisiko zugeordnet werden können, sind Fluorhaltige Tenside die in Löschschäumen vorhanden sind. Diese Löschschäume kommen z.B. auf dem Helikopterdeck von Offshore Plattformen zum Einsatz und können im Falle eines Unfalls in die Meeresumwelt eingetragen werden. Weiterhin werden Kraftstoffe wie Diesel geschlossenen Systemen mit erhöhtem Unfallrisiko zugeordnet, da diese in großen Mengen mittels Bunkern angeliefert werden, was im Offshoreeinsatz mit erhöhtem Unfallrisiko infolge e.g. menschlichen Versagens einhergeht. Kraftstoffe sind in großen Mengen auf Offshore-Umspannwerken oder Offshore Transformerplattformen vorhanden und werden zur Notstromversorgung verwendet. Auch Schmier- und Getriebeöle können ihrem Einsatz in geschlossenen Systemen mit erhöhtem Unfallrisiko zugeordnet werden, sofern sie in externen technischen Anlagen im Außenbereich Anwendung finden (z.B. Krananlagen). Insgesamt 89 Gefahrenstoffe konnten in geschlossenen Systemen identifiziert werden. Diese Gefahrenstoffe sollten jedoch nicht in die Meeresumwelt gelangen, sofern kein Unfall oder menschliches Versagen vorliegen.

Im Rahmen der Studie wurde festgestellt, dass in der deutschen ausschließlichen Wirtschaftszone (AWZ) derzeit keine spezifische technische Richtlinie für die Anwendung und Verwendung von wassergefährdenden Stoffen existiert. Zwar gibt es eine Verordnung über den Einsatz und die Verwendung von wassergefährdenden Stoffen für den Einsatz an Land und in Küstengewässern (12 Seemeilen Zone), jedoch ist diese in der ausschließlichen Wirtschaftszone, in der die meisten Offshore-Windkraftanlagen gebaut werden, nicht anwendbar. Einige allgemeine technische Anforderungen, um Emissionen so weit wie möglich zu minimieren, sind im Flächenentwicklungsplan vorgesehen (BSH, 2020). Bauliche und betriebliche Sicherheitsmaßnahmen müssen jedoch auf Einzelfallbasis sichergestellt werden.

Es ist zu erwarten, dass Beste-Praxis Regelungen für bauliche Maßnahmen zur Vermeidung von Schadstoffemissionen an Offshore-Windkraftanlagen das Risiko einer ungewollten Freisetzung begrenzen können. Darüber hinaus unterstreicht der festgestellte Zusammenhang zwischen menschlichem Versagen und Emissionen aus geschlossenen Systemen die Bedeutung von strengen Routinen, Sicherheitsprotokollen und erfahrenem Personal für die Wartungsarbeiten an Offshore-Windstrukturen.

Die Studie hat auch gezeigt, wie schwierig es ist, gefährliche Komponenten in Betriebsstoffen zu identifizieren. Oft gibt es keine offenen Informationen über die Bestandteile von Betriebsstoffen, z. B. in Sicherheitsdatenblättern (MSDS). Eine bessere Verfügbarkeit der von den Herstellern bereitgestellten Informationen kann einen unvoreingenommeneren Umgang mit den Materialien ermöglichen, eine breitere und einfachere Suche nach Ersatzstoffen erlauben und das Bewusstsein für Risiken schärfen.

1 Introduction

1.1 Motivation

The offshore wind industry is a relatively young industry, but the market has been growing significantly in the last years. This trend is expected to be ongoing to fulfil the EU strategy proposed to increase Europe's offshore wind capacity to at least 60 GW in 2030 and 300 GW in 2050 (European Union, 2020). Also, Germany formulated the goal to increase the offshore wind energy capacity in the offshore wind energy act (Windenergie-auf-See-Gesetz, WindSeeG) to a capacity of 20 GW till 2030 and 40 GW till 2040 (WindSeeG, 2016). Knowing about this trend, it is important to become aware about the impact of the fast-growing wind energy industry on the environment. Until today the environmental impact of the offshore wind industry regarding chemical emissions into the aquatic environment has not been assessed comprehensively. With regard to the fast growth of this industry, it is important to assess chemical emissions and scout opportunities to reduce or prevent these emissions and their potentially negative effects on the marine environment.

1.2 Goal of the project

On structures related to the offshore wind industry various operational materials are required for a smooth operation of different technical installations. These operational materials can contain hazardous substances to the aquatic environment. In the permitting procedure for offshore windfarms in Germany, it is therefore important to define requirements for the use and handling of materials which may release hazardous substances to the marine environment, and which specify the current requirements of the site development plan (BSH, 2020) in more detail. The aim of this research project is to create an overview of the most relevant hazardous substances, which can be emitted to the marine environment due to offshore activities from offshore wind turbines or platforms. Thereby, this report focusses on material emissions into the water. Emissions of light, underwater noise, temperature, or carbon dioxide (CO_2) are not part of this study. Further, the emission of particles originating from e.g. rotor blades or operational materials from cleaning of rotor blades are not considered in this study.

For this overview, a list of operational materials is generated, which gives an idea of the application purpose and amounts of the applied operational materials. Further, how and in which amounts the applied operational materials can be emitted into the environment is investigated. A list of hazardous materials, which includes hazardous substances derived from the operational material list is determined. For up to 50 hazardous substances, it is investigated if and in which amounts the individual substances have been measured in water, sediment and/or biota in the North- or Baltic Sea.

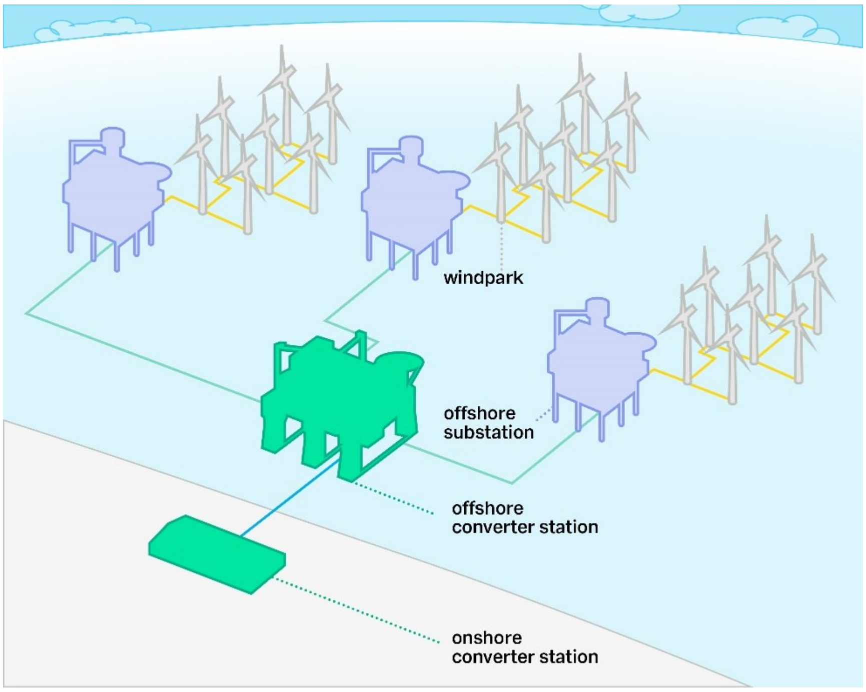
This project was only possible in close cooperation with the Bundesamt für Seeschifffahrt und Hydrographie (BSH). The BSH provided us with detailed information on emission and waste- and operational materials concepts of existing windfarms, which have been a valuable data source for this project. The original BSH documents are not publicly available.

2 Introduction to Offshore Wind Industry

2.1 Structures and Infrastructure of Offshore Wind-Industry

The generation of offshore wind power and the transmission to shore requires various types of offshore structures. Figure 1 provides a schematic overview of the offshore structure types in the North Sea. In an offshore wind farm, power is generated via offshore wind turbines in the form of alternating current (AC) at medium voltage. A group of turbines is connected via array cables (yellow in Figure 1) to an offshore substation, where the medium voltage is increased to high voltage of approx. 150-320 kV. In the North Sea, the high voltage alternating current of several substations is transmitted to an offshore converter platform. In the OCP, the alternating current is converted to direct current (DC) to reduce the energy loss due to the transport distance to shore via an export cable (blue cable Figure 1). In new connection concepts in the North Sea, the OWTs are going to be connected directly with the OCPs (BSH, 2020). Thereby, the construction of an OSS becomes unnecessary in the North Sea, which leads to significant cost reductions for the wind farm development. All wind farms, which are connected to a certain converter station, belong to a power cluster. The direct current is transmitted to a converter station on shore, where the current is adjusted to the requirements of further usage. In the Baltic Sea, the transmission distances are shorter compared to the North Sea. Thus, the transmission is conducted by three phases alternating current, directly from the OSS to shore. The power transmission is realised by medium- or high-voltage offshore cables. More information on the actual and future transmission concepts in the German North- and Baltic Sea can be found in e.g. BSH (2020).

Figure 1: Overview of elements in an offshore wind farm



Source: Deltares 2022.

In the following, the main characteristics of each structure within an offshore wind farm are summarised to give a better understanding of the usage, components, and operations of the individual structures. Further, the presentation of structural components shall give a better insight into the location of application for certain operational materials or the location of other sources of possible emissions. The presented structural components are referred to in the substance lists provided in Chapters 4, 4.2 and 4.3.

2.1.1 Offshore Wind-Turbines (OWT)

The basis of each offshore wind turbine is its foundation, which consists of a support structure and associated substructure where required. Today many foundations exist such as monopiles, tripods, jackets, gravity-based structures. A detailed overview of the various foundations is depicted in Wind energy -The facts (n.d.). Regarding the local geophysical, hydrodynamic and metocean conditions different foundation types are prioritised. In shallow waters such as the North-sea (up to approx. 40 m depth), monopiles (MP) are the predominant type. Based on the chosen foundation type and the local seabed dynamics, a scour protection is often required.

In some cases, a substructure (transition piece) is placed on top of the foundation to transfer the loads and weight of the wind turbine tower to the foundation. If the substructure is installed offshore on the foundation, it is grouted or connected via a flange connection onto the support structure. The substructure includes a boat landing area, working platform and cable connection and allows access for maintenance (see for impressions Stoprust (n.d.) and Offshorewindindustry (n.d.)).

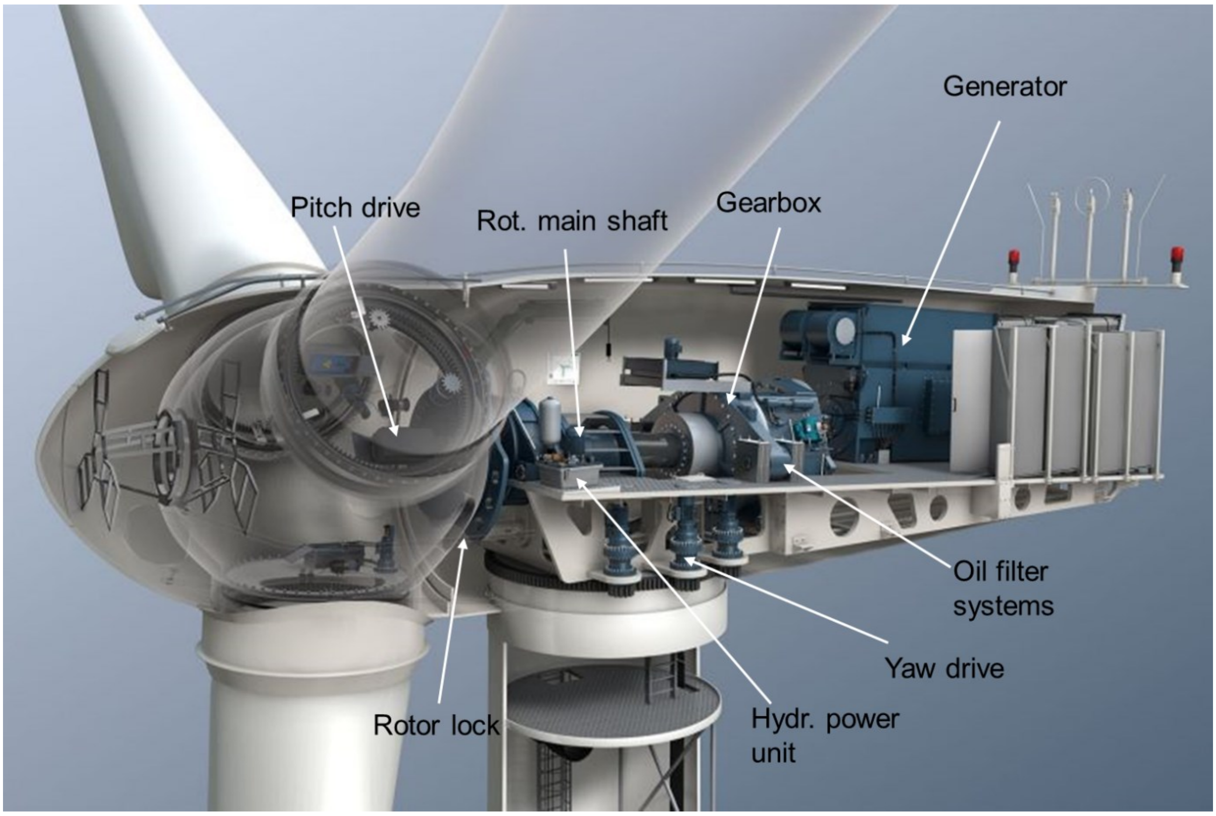
On top of the transition piece the tower is installed. The tower itself houses barely any technical components but might include an emergency power generator or a tower damping system.

The wind power is generated in the nacelle on top of the tower. The nacelle is connected to the rotor. Thereby, the rotor blades are connected to the main shaft in the hub, positioned at the wind facing side of the nacelle (see Figure 2). A pitch drive allows an adaption of the blades pitch to the wind speed.

From the main shaft of the hub, the speed of the rotor is transferred to the so-called drive train. The drive train includes all components from the main shaft to the generator. Drive trains can be mainly distinguished into systems with and without gearbox, but also other hybrid technologies are tested (European Wind Energy Association (EWEA), 2009). The most common representation of a drive train is the solution with a gearbox presented schematic in Figure 2. Thereby, the main shaft is connected to a gearbox. The gearbox increases the rotational motion of the main shaft before it is fed into the generator (van de Kaa, 2020).

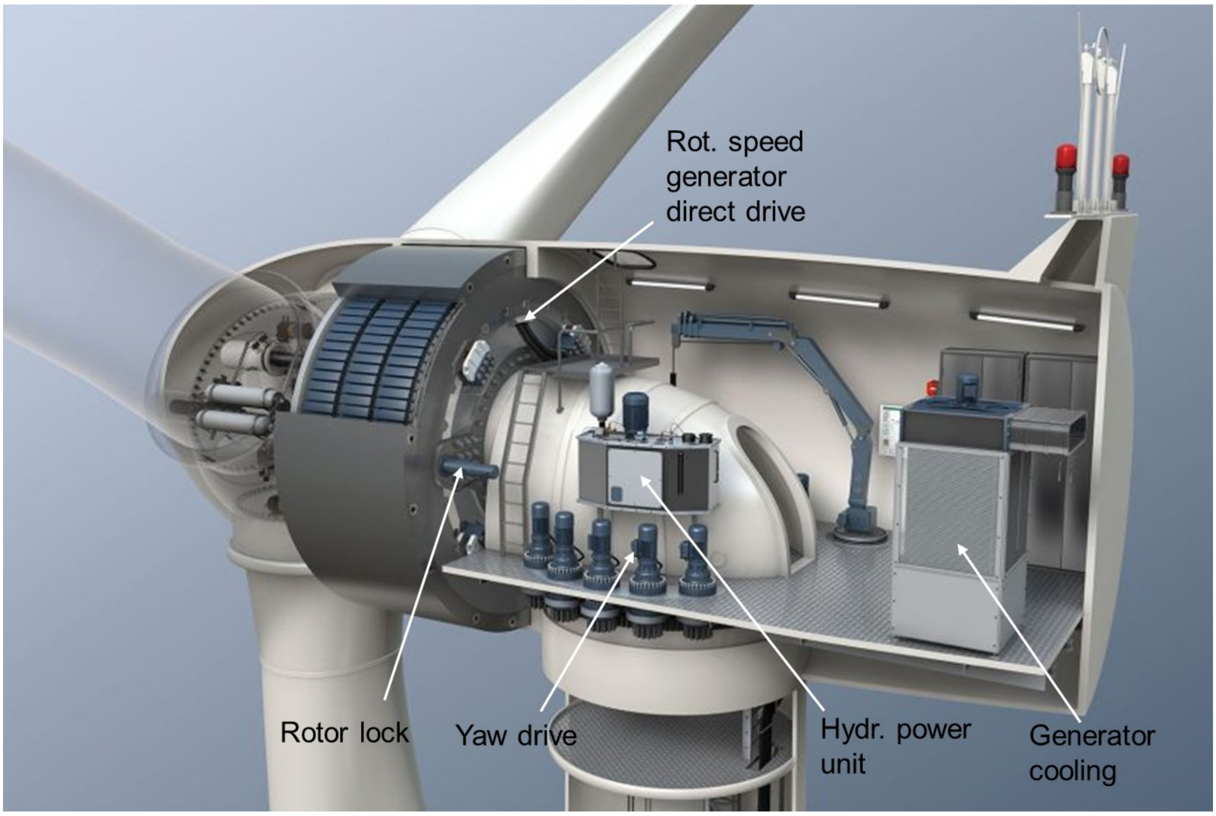
In contrast, at the direct drive solution without a gearbox rotational motion of the main shaft is directly connected to the generator (see Figure 3). Thus, generator speed and rotor speed are equivalent. Due to the lower generator speed, the generator requires a larger number of magnetic poles to achieve sufficient high output (e.g. permanent magnet generator (PMG)). Direct drives supersede the intense maintenance of gearboxes (high amounts of gear oil and lubricants) and the risk of gearbox failures (van de Kaa, 2020). However, for the production of the specific generators applied at direct drives, a higher amount of rare-earths is required than for the common generators applied in gearbox-based drive trains (Wittrup, 2011). For a more detailed discussion on the pros and cons of various drive trains, see Osmanbasic (2020).

Figure 2: Wind turbine with gearbox



Source: IFM (n.d.) (adapted)

Figure 3: Wind turbine without gearbox (direct drive)



Source: IFM (n.d.) (adapted)

2.1.2 Offshore Substation (OSS)

Depending on the capacity of an offshore wind farm, often one or more offshore substations are placed in a wind farm. The OSS stabilizes the generated power and maximizes the medium voltage to high voltage. In the case, the OSS is positioned not too far from shore, the power transmission to shore can be performed at HVAC. Otherwise, a HVDC converter station is of economic interest to reduce transmission losses. If a converter platform is present, new concepts allow also the direct connection between the low voltage turbine grid and the converter platform, without the circuitous route over the OSS.

The OSS structure consists of a foundation and the topside structure (see Figure 4), whereby the foundation types vary. The OSS topside is normally completely constructed onshore and installed via heavy lift vessels.

Figure 4: Example of offshore substation

Source: AdobeStock

The OSS topside consists of several levels each housing different facilities. However, the arrangement of the typically housed facilities varies for different OSS. Thus, in this section the most relevant facilities are presented without assignment to a certain location.

The main facilities on an OSS are the electrical high-voltage and medium voltage components for power transformation. This includes transformer and switchgear equipment and associated auxiliary technique such as e.g. cooling circuits. Further, the OSS houses control and battery rooms. Auxiliary generators and emergency generators ensure the functionality of the station in the case of a grid failure/maintenance work or total black-out respectively by providing power for lights, safety systems, data and control systems. The generators run on diesel, which is stored in diesel tanks on the lower decks. The diesel tanks are filled from ships by bunker processes. The stored diesel tanks need to provide enough fuel to run the generators up to several days.

In all areas of the OSS, fire protection systems are installed, which are customised to the local facilities. All liquids. which might result from leakage or fire protection, are collected in a sump tank on the lower decks. Rainwater from the top deck originating from areas with a risk of spilling of operational materials is collected in a separate tank and is treated by and oil-separator. The treatment of the separated water varies for different substations. More details on this are provided in section 4.2.1.2.1. Furthermore, the OSS provides storage rooms for operational materials or maintenance equipment for the OSS or the OWTs.

To allow fast access to the OSS for operation and maintenance work, an OSS is provided besides a boat landing area also with a helicopter landing platform which is typically positioned on the top deck. For emergency situations, a kerosene tank can be provided near the helicopter landing platform.

The supply with various operational material or other equipment is mainly provided by ship. Therefore, a crane is installed in the outside area of an OSS.

In the most cases, OSSs are designed for unmanned operation but provide emergency accommodations. Thus, an OSS also includes sanitary rooms, accommodations, and food supply.

2.1.3 Offshore Converter platform (OCP)

An offshore converter platform is required for transformation of AC to DC power. DC transmission has the benefit of more efficient transmission of large quantities of electric power over a long distance. Furthermore, less materials are required since DC cables need only one power line in contrast to three at AC power transmission. According to Våbenø (2018), the costs of a converter platform become economically favourable at a distance of 50 km; if the costs of material and power losses are included. A converter station offshore requires further converter station onshore to convert the DC back to AC.

Just as the OSS, an OCP consists of a foundation and the topside structure, whereby the topside is normally completely constructed onshore and installed via heavy lift vessels. It consists of several levels with different facilities.

The main facilities on an OCP are the components for power conversion. This includes conversion-transformer, switchgear equipment, harmonic filters and associated auxiliary technique such as e.g. cooling circuits. Further, the OCP houses control and battery rooms, emergency accommodations and storage rooms. Typically, OCP's have a helicopter platform, which represents the primary access to the platform. The individual rooms include safety measures for e.g. fire-emergencies and leakages. Thereby, the measures are adopted to the purpose of the unit. Specific hazardous substances depots (e.g. coating storage room and gas storage room) include structural protective measures to prevent the emission of materials into the environment. This hold also true for areas where high volumes of operational materials are applied.

Auxiliary and emergency generators ensure the functionality of the station, in the case of a grid failure/maintenance work or total black-out respectively by providing power for lights, safety systems, crane, communications, data and control systems. The generators run on diesel, which is stored in tanks on the lower decks. The diesel tanks are filled from ships by bunker processes. The stored diesel tanks need to provide enough fuel to run the generators up to approx. one month.

2.1.4 Power cables

The transmission of produced offshore wind power is transmitted via submarine cables. Depending on the characteristics of the transferred power, the applied cables are optimised to medium or high voltage and AC or DC power transmission. The main components of submarine cables are the main conductor, insulations, screening, armouring and the outer protection (see Figure 5). The size of the cable and also the applied materials can be particularly adapted to its use. The conductor is normally made of copper or aluminium wires, whereby copper has much higher electrically conductive properties, and it is therefore often preferred. (Vånebø, 2018). For a power transmission via an AC system, 3 transmission conductor cores are required, whereby each core represents on phase. The three cores can be arranged in separate cables or in a single bundled cable with three core formation. A DC system requires one or two conductors, depending on a monopolar or bipolar system. In the case of two conductors, those can be arranged in a separate cable, bundled or in a co-axial manner (ESCAEU, 2021). According to OSPAR (2012), cables can be further distinguished by its insulation to

a) mass-impregnation (MI) cables (non-pressurised fluid impregnated paper),

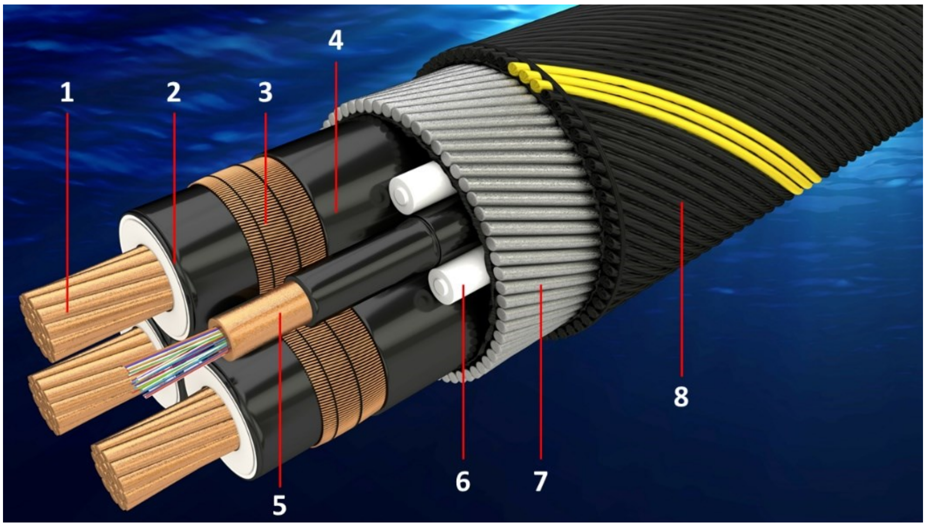
b) cross-linked polyethylene (XLPE) cables (solid dielectric material),

c) fluid-filled (SCFF) cables (insulating fluid under static pressure) or

d) gas filled (SCGF) (insulating gas under static pressure) cables.

MI cables are the most applied cables, since they have proved a high reliability for more than 40 years (Ardelean, 2015). The serving and armour are mostly consisting of polyvinylchloride (PVC) or polyethylene (PE) sheath and layers of polypropylene (PP) yarns (Ardelean, 2015).

Figure 5: Exemplarily design of a subsea power cable. The construction varies with the technique and manufacturer.



1 – Conductor
2 – Insulation with insulation screening
3 - Screen
4 - Laminated sheath
5 – Optical fibre cable (optional)
6 - Fillers
7 - Armour (e.g. galvanised round steel wires)
8 - Serving

Source: Adobe Stock (adapted)

Usually, submarine cables are obliged to be buried in the ground. Although, it is a cost-intense installation process, the burying increases the expected cable lifetime and reduces the risk of failure due to external influences such as vessel anchoring or fishing activities. Especially, in the sandy grounds as e.g., the North Sea, the bed surface is expected to alternate much due to morphodynamical features such as sand waves. Thus, the burial depth needs to be estimated carefully, to ensure a covering by sediment over the whole guaranteed 25-year life span of the cable (Ardelean, 2015). When crossing other subsea line infrastructure (e.g. telecom cables or pipelines), the cables are not buried but instead cable crossing structures are constructed. In these structures, the cable infrastructure is separated typically by concrete matrasses. To protect the cables from exposure, typically additional scour protection is applied in the form of concrete matrasses or loose rock.

2.2 Life cycle of Offshore Wind Structures

The life cycle of offshore wind structures begins with their design. Subsequently, the individual parts are produced onshore. Thereby, most of the structure components are already completely assembled in the case of the functional part of the structure such as the turbine consisting of tower, nacelle and (often) rotor or the complete OSS/OCP top structures. The foundations are assembled as individual parts as well and are the first to be installed offshore. The installation of the offshore wind structures is realised with various specialised vessels ranging from normal mono-hulls to jack-up or even semisubmersible vessels with heavy lifting equipment. As a last installation step, the OWT are connected to the OSS, the OCP and the onshore grid by offshore cables, mostly embedded into the seabed. As for the offshore structures' parts, also the power transmission cables are manufactured onshore and are placed with specialised cable-laying vessels. After the installation of the offshore structures, the operational life phase begins. Generally, offshore wind structures are designed for an operational lifetime of min. 20 years (BSH, 2015) to approx. 25 years. New wind farms are considered for even 30 years of operational lifetime. During this operational phase, periodically maintenance works are carried out. At the end of the operational lifetime the structures can be converted or decommissioned. An example on reuse of old offshore infrastructures is e.g. the modification of old offshore platforms for CO_2 storage or for offshore hydrogen production.

For this study only the lifecycle stages offshore are of interest, since those could lead to the emission of substances into the marine environment. Thus, the following section discusses the potential emissions during the installation, operation and decommissioning life phase.

2.3 Regulatory framework on offshore emissions

The chemical emissions from offshore wind farms during construction, operation and decommissioning are described but still leave open questions. Chemical emissions from the offshore wind industry may originate from both the operation as well as the traffic related to the operation of the wind farm. Typical chemical emission release scenarios are the re-mobilization of contaminated sediment due to seabed disturbance by subsea cable and foundation construction, discharges from waste water treatment plants and cooling water from platforms, artificial scour protection materials, corrosion protection measures, atmospheric emissions from diesel generators, direct chemical emissions and spills during accidents (e.g. fire on platform and the use of firefighting foams or accidental spills of oil, lubricants or coolants) (Kirchgeorg et al., 2018).

Procedures and constructive preventive measures are thought to be key in reducing the likelihood of chemical emissions greatly. In most European countries preventive measures (as e.g. backup systems, secondary containments, closed loop systems and recovery tanks) and procedures are included in the permit application of the wind farms from a Health & Safety point of view. However, it is very apparent that impact on the environment in particular during operation are not widely studied. A good reflection of the environmental awareness of the wind farm industry and responsible permitting authorities is the review of Environmental Impact Assessment (EIA) that will be required for most offshore wind farm projects. These EIAs show that impacts from chemical emission is considered small and that procedures and preventive measures are a suitable means to mitigate the risk of emission even further.

Nevertheless, the wind industry strives to become even less polluting with e.g. the development of biodegradable lubricants for hydraulic systems (Dvorak, 2015) or a zero-waste turbine (Vestas Wind Systems A/S & Siemens Gamesea Renewable Energy SA (Gualtieri, 2021)).

In the following, the existing regulatory framework relevant for offshore emissions are presented and compared. Thereby, the frameworks for the countries of Germany, The Netherlands, United Kingdom and Denmark are taken into account.

It is noted that this framework focusses on emissions due to construction and operation of a wind farm. It is noted that there are for all 4 countries design criteria of wind farms that have to be fulfilled as e.g. the need to install secondary containment for oil storage or an overfill protection for storage tanks. These are not specifically for wind turbines are in general applicable to all storage facilities (not only offshore).

2.3.1 Germany

In Germany the construction of an offshore wind farm needs to be permitted following the Wind Energy on Sea Act (WindSeeG) superseding the offshore Installation Ordinance (Seeanlagenverordnung). The competent authority is the Federal Maritime and Hydrographic Agency (BSH) for the EEZ and authorities of federal states for the 12 nm zone.

To ensure that shipping, air traffic and the marine environment do not experience any deterioration of safety or suffer negative impacts, an environmental impact assessment will be carried out considering these impacts. The environmental impact assessment will include emission studies, waste & materials usage, investigation of alternatives and emergency plans. There is no legislative framework to require the best available technique, however as competent authority BSH has the opportunity to include individual permit measures for the construction of the commissioning of an offshore windfarm. This allows for more flexibility, but also possible stricter measures than legally required. To ensure that these measures are followed is part of the enforcement procedure (BSH, n.d.).

The planning approval procedure following the Site Development Plans (FEP) requires documents and drawings for the entire project to show that it fits within this framework. This also includes a so-called declaration of commitment for the surrender and transfer of ownership of the wind farms to any subsequent users in the event that the plan approval decision becomes invalid (see section 66 subsection 2 of the WindSeeG) (BSH, 2019b).

For the commissioning and operation of offshore wind industry structures, such as offshore wind turbines, substations and converter platforms, avoidable emissions of hazardous substances into the marine environment need to be prevented. The objective that marine waters should be managed to maintain or achieve good status is set out in the Marine Strategy Framework Directive (MSFD), which is nationally implemented through the Wasserhaushaltsgesetz (WHG) and for areas within the 12 nm zone this is specifically regulated by the “Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen“ (AwSV).

The AwSV provides a clear framework for the handling of hazardous substances applied in technical installations for offshore structures within the 12-mile zone. It includes a concept of classifying individual substances into hazardous classes and guidelines for structural measures as well as organisational measures for the limitation of emissions into the environment within various technical installations.

The permitting authority for the coastal areas of the 12 nm zone is the federal states. The competent authority for the Exclusive Economic Zone (EEZ) is BSH.

As mentioned, some legislation (e.g. the AwSV) is not applicable in the EEZ. Therefore, the BSH will rely to a large extent on the emission studies, waste and operating material concepts, emergency response plans etc. that also inform the Environmental Impact Assessment (EIA). Regional and European legislation such like the OSPAR convention and the Birds and Habitats

Directive are valid. Additionally, the BSH can as competent authority enforce the adhering of certain requirements as part of individual permit measures. These sort measures are often discussed with UBA before inclusion into the permits for the wind park operators.

This approach will rely on the perception that requirements from the permits are implemented and followed.

2.3.2 Netherlands

The offshore wind energy act entered into effect on 1 July 2015, giving the Minster of Economic Affairs the base to consider amongst others the environmental and ecological interest. This means the decision on the siting of a wind farm will need to include terms and conditions in relation to the protection of the environment, the preservation of Natura 2000 areas under the Nature Protection Act (Wet Natuurbescherming, 2017).

An environmental impact assessment is mandatory for all wind farms with more than 20 turbines under the “Besluit mer” category C22.2 (smaller wind farms may still need to have an environmental evaluation). These assessment and evaluations will feed into the permitting application.

For any construction to be built offshore within the territorial waters of the Netherlands, a permit according the Water Act is mandatory, as this ultimately allows the introduction of a structure onto the seabed. Furthermore, within the 12-mile zone, the integrated physical environment permit (Wet algemene bepalingen omgevingsrecht, 2008) will need to be acquired or at least a notification in line with the activities decree (Activiteitenbesluit milieubeheer, 2007).

Environmental permits will be provided by Rijkswaterstaat. However, additionally, different spatial permits relating to the location and the use of seabed/land may be needed to be obtained.

In the (environmental) permit application, any wind farm developer will need to describe how environmental impact will be managed, which measures will be put in place and justify the technical design. The EIA is a part of this permit application.

In the past emissions from wind farms have been addressed in EIAs to some extent. This relates in particular to effects related to incidents and the transport of dangerous goods to the platforms. However, incidents are classified as rare and with appropriate mitigation measures (use of drip trays, well defined procedures) are not further elaborated. Leakage due to collision offshore is classified as even smaller. Some EIAs mention the use of sulfur hexafluoride (SF_6), but again, due to the small quantities and procedures around maintenance this has been classified as acceptable.

Outside the EEZ the legal framework consists of the Birds and Habitats Directive, the National Ecological Network (EHS) and the OSPAR convention.

In the Netherlands, the National Mines Inspectorate (Toezicht op de mijnen) is tasked with the supervision of offshore wind farms. This begins with involvements (in terms of permitting) when the wind farms are designed and will continue with inspection to ensure that wind farms operate within the given permits. Here the importance of proper operation and emergency procedures in the prevention of emissions/leaks/accidental spills is acknowledged.

It is noted that according to the yearly report in 2019, the Inspectorate steps up the need for supervision with the increase in offshore wind farms. More personnel are attracted to increase the number of inspections of existing and future wind farms.

2.3.3 Denmark

Denmark has a long-standing history in offshore wind with it being part of the Danish energy strategies for decades. According to DONG energy et al. (2006) belongs the right to exploit wind energy within Danish waters to the State and permission to conduct preliminary studies and to exploit wind energy at sea is granted by the Danish Energy Authority. Offshore wind farm projects may only be carried out based on a detailed EIA and after the general public, the authorities and organisations concerned have had an opportunity to express their opinions (DONG energy et al., 2006). Once the EIA procedure has been completed, and the deadline for appeal has expired, the Danish Energy Authority grants the final approval. Recently, a Strategic Environmental Assessment must be completed prior to the Environmental Impact Assessment in order to ensure that the project can fit in with existing (spatial) plans.

The overall environmental conditions constituted the basis for regulatory requirements as specified in the approval of the projects. Therefore, these environmental demands will be translated into requirement specifications to the suppliers and contractors. For the operational purposes, it is common to have environmental management systems established for wind farms. This ensures that procedures and instructions for all personnel on the sites are specified to ensure correct handling of environmental issues such as general working procedures, waste handling, noise measurements, emergency protocols and contingency plans for accidents and spills.

Environmental impacts typically addressed during construction and operation include sediment spill monitoring, accidents and oil spills, waste handling, noise/vibration (depending on base of wind turbines), sediment deposition, marine archaeology and navigation as well as impact on the marine fauna and birds.

Of these only the accidents and spills will possibly contribute to emissions from offshore wind farms. Proposed de-risking/mitigation of these emissions is mostly related to procedures and contingency plans, also for navigation, e.g. by defining such as navigational corridors to reduce collision risk.

2.3.4 UK

The UK can permit offshore wind farms depending on their capacity under the Planning Act 2008 that will require a development consent order from the Secretary of State for the Department for Business, Energy & Industrial Strategy (BEIS) or for wind farms with capacity of less than 100 MW a section 36 consent under the Electricity Act 1989 which will be granted by the Office of Gas and Electricity Markets (Ofgem). Ofgem can include standard and special condition with the license. If significant environmental impacts are expected, an EIA may be required.

There has been some effort into developing a one-shop- stop for permitting in the UK (for permit for site visit, allowing as well to take measurements, planning permit, land use permit/approval, building permit/installation permit/zone permit, environmental impact assessment, interconnection agreements) (Wind Energy -The facts(n.d. b)). The UK's Department for Energy and Climate Change (DECC) has developed a Renewable Energy Strategy and the Office for Renewable Energy Deployment which acts as a one-stop shop and information portal (Mueller, 2015).

In parallel to the other countries investigated, also in the UK, the environmental impact assessment is the main tool to address emissions to the environmental from wind farms as it is part of the permitting procedure.

3 Investigative approach of this study

There is no comprehensive overview yet on potential chemical emissions from the offshore wind industry. As presented in section 1.2, a first overview will be determined in this project. To achieve a comprehensive insight into processes, associated operational materials and potential emissions, it is necessary to distinguish between individual structures and the different life phases of these structures. Structures of the offshore wind industry include a high number of offshore turbines, substations, converter platforms and cables. Further, the life phases of the individual structures will be distinguished, since different processes are taking place offshore during e.g. installation, operation and decommissioning phase.

The investigative approach of this study can be distinguished into individual steps:

1. Identification of processes and techniques on the individual offshore structures during different stages of the lifecycle, which can be associated to potential emissions (see Section 3.1);
2. Analysis of application and location of operational materials applied during wind farm operation and classification to application in open/closed system (see Section 3.2);
3. Identification of substances contained in operational materials (see Section 3.2);
4. Identification of hazardous properties of individual identified substances (see Section 3.3);
5. Association of hazardous substances to processes and techniques (see Section 3.4);
6. Analysis of measured occurrence of identified hazardous substances in the environment.

The individual steps are further elaborated in the following sections.

The investigative approach of this study as well as first results have been presented and critically discussed in a workshop with experts from UBA and BSH in the field of chemical evaluation (REACH, biocides, pesticides), security of installation, and offshore wind permitting. Due to the confidential nature of the data, the participation in the workshop had to be restricted to UBA and BSH experts. The most relevant information/ conclusions of this workshop are attached in the Appendix **Fehler! Verweisquelle konnte nicht gefunden werden.**.

3.1 Identification and analysis of processes associated to potential emissions

In the first step, techniques and process during the lifecycle of individual offshore structures are assessed (see section 4). Therefore, the transport and installation techniques during the installation offshore (see section 4.1), the processes during wind farm operation (see section 4.2) and the techniques for various forms of decommissioning (see section 4.3) are analysed. In the case that a process or a certain method can be associated to the application of chemicals via operational materials, the applied materials are analysed regarding their hazardous properties.

By means of a close collaboration with the BSH, waste- and operational materials concepts and emission studies of various offshore wind-structures in the German EEZ could be examined in this project. The waste- and operational materials studies give detailed information on the individual operational materials, which are present during operation of the offshore structure. The provided information on the German EEZ included the concepts on the turbines and substations of 13 wind farms in the North - and Baltic Sea as well as 3 converter platforms. For the development of an operational material list, in total 9 different wind farms with individual designs for the turbines and substations and 3 converter platforms have been investigated in detail for the associated operational materials and corrosion protection measures. To give a comprehensive overview on the operational materials, wind farms with different turbine models have been selected. Thereby, gearbox and direct drive-based drivetrain technology is included.

Based on the total number of wind farms installed (27) in the German territories in beginning of 2021 (Offshore Windindustrie, 2021), the information received is deemed representative for the current situation in the German wind energy industry. Based on the identified processes and associated operational materials, a list of operational materials was developed. The operational materials lists include the related process and application location within the structure as well as more detailed information on the operational material. Further, operational material classes are introduced, which are presented in section 4.2.1.

Based on the application and location of an operational material, each operational material has been categorised to application in an open or closed system. Operational materials applied in an open system are emitted directly into the sea water. Operational materials applied in closed systems are not in direct contact with the sea water but can be emitted due to an accident. More details and further subcategories, representing different probabilities of spillage, are given in section 4.2.1.

3.2 Identification of substances in operational materials

Operational materials are mostly mixtures, composed of various individual substances and are required for smooth operation of technical installations or maintenance of the offshore structures. The actual composition of operational materials is in most cases highly confidential. However, material safety data sheets (MSDS) give information on potential hazards associated with a particular operational material due to its substance composition. Thereby, each substance can be identified with a unique Chemical Abstracts Service (CAS) number, which represents a unique numerical identifier from the Chemical Abstracts Service. Based on this CAS number, additional information can be obtained. For most of the operational materials, the MSDS were present in the information from the specific wind farms provided by BSH. For a few operating materials, the MSDS could be found by cross-references with other wind farms. For some operating materials the MSDS were missing. Only for those operating materials used in open systems and/or used in substantial amounts the missing MSDS were searched for on the internet.

As described in section 1.2, hazardous substances within operational materials shall be identified and further investigated. The product of this investigation is a substance list, including all individual substances present in operational materials used on the investigated offshore wind structures, which are going to be further distinguished by their hazardous properties (see section 3.3). For all individual substances identified by CAS numbers, physical/chemical characteristics, properties of Persistency, Bioaccumulation and Toxicity (PBT) and other relevant parameters, such as the origin of the substance and the risk classification are gathered and compiled. For risk classification information regarding Globally Harmonized System of Classification and Labelling of Chemicals (GHS-classification) (United Nations, 2021) and H-phrases (Hazard phrases) according to CLP (Classification and Labelling of Chemicals) Regulation (European Commission, 2008) were included. For most substances, information was available from the ECHA (European Chemical Agency) website (ECHA, n.d. a). In case that an ECHA registration dossier as well as an ECHA substance information file are available, the information from the registration dossier was consulted. This dossier includes more detailed information on the substance.

The application of an individual substance can be traced back to an operating material by an additionally linking table. The linking table does not include detailed characteristics of the substance but links the substances to the associated operational material, process and application location.

3.3 Identification of possibly hazardous substances

All individual substances are checked for occurrence on the SIN-list (Substitute It Now) by ChemSec (International Chemical Secretariat) (ChemSec, n.d.), the REACH list of Substances of Very High Concern (SVHC) (European Commission, 2008), list the OSPAR list of chemicals of priority action (OSPAR, n.d. a), the OSPAR list of substances which Pose Little or No Risk to the Environment (PLONOR)(OSPAR, 2021), the OSPAR list List of Substances of Possible Concern (OSPAR, n.d. b) and the ECHA list of endocrine disrupting chemicals (ECHA n.d. b). Further, 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 is the national implementation of the Water Framework Directive (EU Directive 2013/39/EU).

All information on the individual hazardous substances is compiled in a table (see Section 5.2.1). The substances identified as non-hazardous according to the criteria applied are presented in a separate table in the Appendix A. Figure 6 presents the headers from the individual substance lists, which have been condensed for the representation in the tables in Section 5.2.1 and Appendix A. In the category column all hazardous substances are identified as 'shortlisted'.

Figure 6: Individual Substance list headers

CAS nr	Substance	Category	PBT	Persistancy (short)	Bioaccumulation (short)	Toxicity (short)	Toxicity (PNEC value)	GHS class

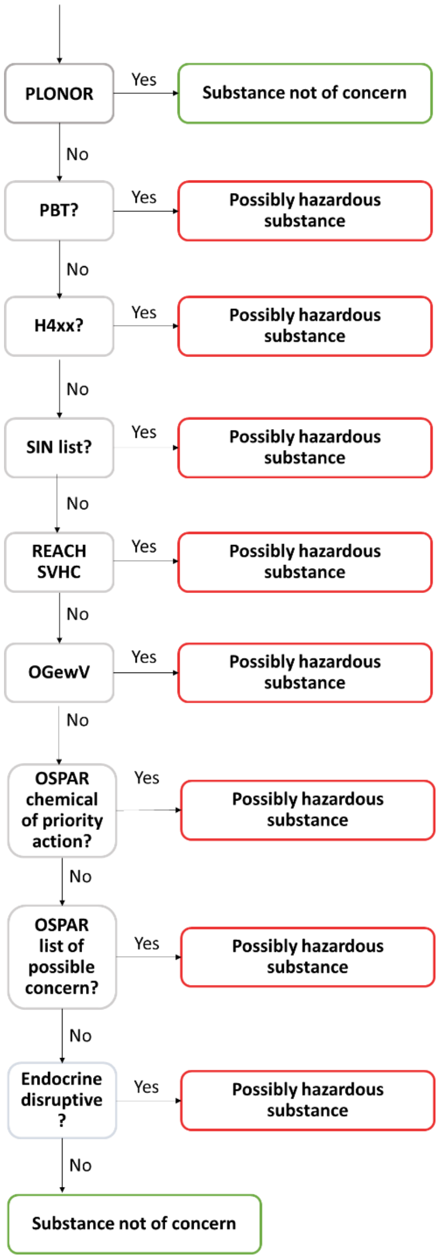
H-phrases	Sin-List	OSPAR list of possible concern	PLONOR	Endocrine disruptive ECHA	SVHC	OGewV	OSPAR chemicals of priority action	Source

Source: Deltares 2022

In the substance list 321 individual substances were included. Most of these substances are not expected to be harmful to the aquatic environment, however, some substances are. A distinction between hazardous and non-hazardous substances according to the criteria applied 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. Hazardous substances are identified by either being persistent and toxic, persistent and bioaccumulative, having an H-phrase related to aquatic toxicity (H4xx) or by being identified on the SIN-list (ChemSec, n.d.), the REACH list of substances of very high concern (SVHC) (European Commission, 2008), OSPAR list of chemicals of priority action (n.d. a), OSPAR list of substances of possible concern (OSPAR, n.d. b), the ECHA list of endocrine disrupting substances (EHCA, n.d. b) or the river basin specific pollutants and priority substances listed in the German Ordinance on the Protection of Surface Waters (annex 6 and 8 OGewV).

In Figure 7 the identification of hazardous substances is illustrated by a flow diagram.

Figure 7: Flow diagram for identification of possibly hazardous substances.



Source: Deltares 2022

3.3.1 PBT criteria

In this study the first criterium is whether a substance is Persistent, Bioaccumulative and Toxic (PBT). Due to their characteristics PBT substances are strictly regulated. In this study the PBT assessment criteria as laid down in the REACH regulation 1907/2006 (European Commission, 2006) were used to determine the persistence, bioaccumulation potential and toxicity of a substance. In Table 1 an example of (some of the) criteria that are used to assess a substance are described. In Annex XIII of REACH regulation 1907/2006 the full criteria for identifying persistent, bioaccumulating and toxic substances are laid down (European Commission, 2006). The assessment of PBT characteristics of a substances were assessed by consulting the registration dossiers or substance information sheets from European Chemical Agency (ECHA) in between March 2020 and June 2021. In case that an ECHA registration dossier as well as an ECHA substance information file are available, the information from the registration dossier was consulted (ECHA, n.d. a). This dossier includes more detailed information on the substance. Registration dossiers contain a number of different information, including general information, physical & chemical properties, environmental fate & pathways, etc. The registration dossier gives further information on classification, labelling and PBT. The PBT status is copied from the PBT assessment information as well as information on GHS classes and H-phrases. More detailed information on biodegradation and bioaccumulation was retrieved from information on Environmental fate & pathways, while detailed information on toxicity was retrieved from the given ecotoxicological information.

Persistent substances require more attention since these substances do not (easily) degrade, cannot be removed from the environment and thus can slowly accumulate in the environment and cause long term effects. In this study therefore also substances that are either persistent and bioaccumulative or persistent and toxic are listed as hazardous. Two out of 321 substances were assessed as being as persistent and bioaccumulative and three substances were assessed as being persistent and toxic.

Table 1: 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
Persistence	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.

3.3.2 H-phrases

H-phrases are used to describe potential hazards with regards to a specific substance (European Commission Taxation and Customs Union, 2019). All substances which have been assigned an H-phrase related to aquatic toxicity have been listed as 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.

Not all substances are officially assigned a H-phrase, therefore substances that are marked as potentially being harmful to aquatic life were listed as possibly harmful to aquatic life. In total 88 out of 321 substances were assigned a H-phrase related to aquatic toxicity. 21 additional substances were listed as being possibly harmful to aquatic life.

Endocrine disruption is currently not assessed via H-phrases, therefore substances have been checked for endocrine disrupting characteristics via the ECHA list of endocrine disrupting substances (ECHA, n.d. b). This list is still under development. Endocrine disrupting substances are able to interfere with the endocrine (hormonal) system. Two out of 321 substances are listed as being endocrine disrupting. Four substances have been identified as possible endocrine disrupting, but the assessments are still under development. Five substances are listed in Annex 8 of the German Ordinance on the Protection of Surface Waters (priority substances under the Water Framework Directive) and two substances are listed as in Annex 6 of the German Ordinance on the Protection of Surface Waters (river basin specific pollutants). Information on these substances can be found in individual substance tables in Section 5.2.1.

A risk classification, based on GHS-classification (Globally Harmonized System of Classification and Labelling of Chemicals), was researched as well. GHS-classes include classes like toxic, (GHS06), long-term health hazard (GHS08) or hazardous to the aquatic environment (GHS09) (United Nations, 2021). 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 (see above).

3.4 Additional analysis of hazardous substances of special interest

Based on the hazardous substance lists generated according to the procedure described in the previous sections, a selection of hazardous substances of interest was made. The substances of interests are selected in accordance with the UBA, based mainly on 4 criteria: First, all substances with PBT criteria are selected. Second, substances are selected which occur on the list of hazardous substances in open systems or closed systems with a higher risk of accidents. Third, substances which are associated with operational materials of volumes higher than 200 l or 200 kg in volume/mass. Finally, individual substances are selected based on expert judgment by UBA. The list of selected hazardous substances of interest is presented in Section 5.3. The selected hazardous substances of interest are further analysed focussing on their specific volume/mass and occurrence in water measurements in the North - and Baltic Sea. The occurrence of the substances in the marine environment is based on monitoring data stored in the German marine environmental data base (Meeresumweltdatenbank, MUDAB).

4 Identification of sources of hazardous substances

4.1 Possible emission sources of hazardous substances during installation phase

During the installation of the individual wind farm structures presented in section 2.1, specialised technical equipment is used such as e.g. heavy lifting equipment, hydraulic aggregates, welding, cutting or other devices. Different oils, lubricants and cleaning agents are used during this phase. Leakage of these substances cannot be avoided completely, as no receptacles can typically be used during this phase. Further, the commissioning of operational systems on the offshore structures during the installation phase can lead to accidental spilling.

4.1.1 Ships

Ships, which enter the construction site of the offshore wind farm, are requested to qualify for the International Convention for the Prevention of Marine Pollution from Ships (MARPOL) of the International Maritime Organisation (IMO).

The installation of offshore foundations, platforms, turbines, scour protection and cables is carried out by specialised vessels. Based on the installation effort, the installation time for those vessels varies. Thus, possible emissions due to vessels will increase with the installation time. Emissions of these ships are similar to those identified for conventional shipping, the most prominent being emissions originating from sacrificial anodes and antifouling paints as well as sewage or bilge waters. As the activity of shipping varies, because of varying environmental conditions, installation techniques maintenance programs etc., the emissions of shipping during the installation and operational phase are hard to quantify. Next to that, although these emissions may cause both a small temporal and spatial peak in substances associated with these emissions, e.g. zinc from corrosion protection, waste waters, oils in general the emissions associated with shipping during the installation phase can probably be neglected compared to the emissions associated with conventional shipping.

In the work package 4 report of this project, we will further elaborate on the emissions of maritime transport.

4.1.2 Foundations

The installation of the foundation includes pile driving of the support structure (except for rarely used GBS foundations). Thereby, heavy techniques such as hydraulic hammers or vibration driving equipment are applied. Those techniques include hydraulic oils, grease or other lubricants in/on the technical equipment during the installation process.

A foundation structure is based on a support structure in combination with a substructure. The substructure (e.g. transition piece) can be connected to the support structure via a grouting or bolted/flange connection. In the case a grouted connection is chosen, grouting material is filled into a gap between the outer shell of the support structure and the inner shell of the transition piece. At the lower edge of the transition piece, a seal closes the grouting gap and prevents a leakage of grouting materials into the water. To establish a sufficient grouting connection, the material is pressed into the ring gap till it comes to a spill over. Due to this spill up to ca. 25% of the overall grouting mass can be emitted into the environment (confidential information from emission study). In the case of a failure of the seal, the whole grouting material of up to 25 m^3 can be emitted into the environment. The MSDS of exemplarily grouting material gives Portland cement (<50%) and calcium oxide (<7%) as hazardous materials. Reaction with sea water and hydration makes it solid. These inorganic materials have neither toxic characteristics nor characteristic hazardous H-phrases (see Substance-list). However, according to the classification provided by companies to ECHA in CLP notifications this substance causes other risks which are not related to the aquatic environment such as eye damage and skin irritation. Both Portland cement and calcium oxide are on the OSPAR List of Substances Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (PLONOR). Therefore, both substances are considered as non-hazardous for the marine environment according to the applied criteria. According to the site development plan (BSH, 2020), grouting material must be as free of pollutants as possible if grouting is applied. Further, appropriate techniques and equipment for the grouting process must be used to prevent the input of grout material into the marine environment as far as possible.

4.1.3 Cable laying

Power cables are a sensitive part of an OWF. In the case of disfunction, the OWF is not able to deliver power, till the cable is back to operation. As stated in section 2.1.4, power cables in shallow waters are protected by being buried in the ground. Often, they are buried to a certain depth. In the case a burial is not possible (e.g. due to exposed bed rock), cables can be also installed on the seabed and are protected by partially or fully protection system such as e.g. sediment, rocks or concrete matrasses (Meißner, 2006). According to the Flächenentwicklungsplan 2019 (BSH 2019), power cables in the German North Sea need to be buried minimal 1.5 m, while the covering height in the Baltic sea needs to be determined by individual studies.

The power cable laying is often accomplished by specific vessels. In this case, the cable is buried as it is laid. In other cases, the subsea cable is positioned on the seabed first, before it is buried at a later stage (Meißner, 2006). The submarine installation technique itself can vary between ploughing, trenching, jetting, dredging and directional drilling (see DNV GL -RP-0360 (2016)).

The emission of substances during subsea power cable installation in OWF's is linked to the mobilisation of sediment. In the case of contaminated sediment at the seabed, the contaminating substances are re-suspended and enter the water column (Tornero, 2016). However, this issue is only valid in contaminated areas (Meißner, 2006). As a prevention measure, heavily contaminated areas should be avoided for cable routing or the sediment quality should be assessed before cable installation to avoid toxic hot spots (Meißner, 2006). In Germany, an environmental impact assessment has to be provided in the application procedure, addressing specifications on cable routing, installation time, burial and cable design (Merck, 2009). Another possibility is to choose for an installation method with least seabed disturbance such as hydro-jetting (Meißner, 2006). The phenomenon of re-suspension is limited to installation, maintenance or decommissioning measures and thus temporarily and further limited to the cable corridor (Merck, 2009).

In case of cable installation with horizontal directional drilling (HDD), drilling liquids are involved (Orsted, n.d.). For HDD in offshore application Bentonite based drilling liquids are applied. Bentonite is a non-toxic, natural clay mineral and is on the List of Notified Chemicals approved for use in the marine environment and is classed as OCNS (Offshore Chemical Notification Scheme operated by Cefas) group E, which is the group least likely to cause environmental harm (Mullan, 2018). To achieve certain liquid characteristics, additives can be used which can be on a natural basis such as polymers on starch bases, viscosity or pH-value regulating additives (van der Waal, 2018).

4.2 Potential emission sources of hazardous substances during Operation or Maintenance

Potential emission sources during the operational phase of an offshore structure are e.g. operational materials applied on the individual platform, open systems with outlets into the sea, corrosion protection measures or interaction processes with different structure parts and the sea-water.

Operational materials are materials, which are required for the trouble-free functioning of the systems on the structure during operation or for maintenance purposes. That can be

- solid consumables (isolation materials, filters, metals, cables, batteries, household or industrial waste),
- liquid materials applied at mechanics or electronics (gear oils, hydraulic oils, insulating fluids, grease, coolants, fire extinguishing material, fuels, coatings) or
- others (process water, service water, drinking water, fire protection, surface waters).

Further, corrosion protection measures, including active and passive corrosion prevention, can be a source of emissions. Waste or garbage materials from offshore windfarms (OWF) are not specifically taken into account in operational or maintenance materials. Waste generated offshore is transported to shore and disposed there.

All these potential sources and their probability to lead to emissions are discussed in the following sections. Besides the previous introduced sources, the interaction between the sea and the structural components and the association to possible emission is discussed further. The sources can be distinguished by the probability of an emission during regular operation, maintenance works or accidentally.

The German Flächenentwicklungsplan (BSH, 2019) states that the environmental impact of operational materials needs to be investigated carefully and the examination of substitutes needs to be performed on regular basis. Environmental-friendly operational materials are preferred.

4.2.1 Operational and maintenance materials in open and closed systems

The term “operational materials” summarises materials which are in operation within technical installations (e.g. hydraulic oils), materials which are stored on an offshore structure as reserve or for maintenance purposes or materials which are applied in fire protection systems. In this study specific operational materials are identified, which might be of concern regarding emissions into the aquatic environment. These are predominantly liquid operational materials such as oils, grease, foams or liquid compounds in solid consumables. In the latter category belong e.g. battery blocks, which are working on lead acid base. In contrast, solid operational materials are not considered. This could be e.g. packings, cables, pipe or hoses, isolation material, lamps, metals or industrial waste.

The following operational materials are identified for offshore wind structures and are investigated further in the following sections and are included in the comprehensive overview in the operational material list (see Section 5.1):

- hydraulic oil
- transformer oil

- gear oil
- grease
- coolants
- fire extinguishing material (foam, liquids)
- fuels (diesel, kerosene)
- cleaning equipment
- grey water
- black water
- rainwater discharge

Maintenance materials are summarized as materials which are stored on an offshore platform for maintenance purposes. This can be also additional amounts of operational materials, which are stored in separate storage rooms. Further maintenance materials include e.g. glues, adhesives, coatings, cleaning agents, water treatment, sanitary supply, corrosion protection materials, sealing compounds, rust dissolvers, grease.

In this study, it is distinguished between operation and maintenance materials in closed and open systems as well as materials which might be spilled in an accident. In the case of a closed system, the material is applied or stored in a sealed environment, with several safety measures to prohibit spilling. In open systems, the material is in direct contact with the seawater in e.g. an open circuit. Materials applied in a not fully sealed environment, but with existing safety measures (e.g. outside) or include transport measures with a higher risk of accidents (e.g. bunkering) are summarised as operational/maintenance possible emitted during accidents.

4.2.1.1 Operational materials and maintenance materials in closed systems

Operational materials are assigned to closed systems, if the materials are applied or stored as reserve or for maintenance within internal and enclosed areas. Thus, under normal circumstances, no leakage and thus unknown emissions from operational materials into the environment is expected. According to current emission studies of various offshore wind farm structures, internal rooms and areas with large amounts of liquid operational materials should have collecting trays or the rooms itself are working as such by design (e.g. diesel storage, transformer rooms). In the case of leakage from rooms or collection trays, the liquid should be directed over an oil water separator system to a sump tank. Currently, no specific technical guideline are applied in the German exclusive economic zone (EEZ) regarding the application and use of substances which are hazardous to the aquatic environment. The German Ordinance on Facilities Handling Substances that are Hazardous to Water (AwSV) on the application and use of substances which are hazardous to the aquatic environment for the application onshore is only applicable by law for coastal waters (12 nautical miles) and not in the exclusive economic zone (EEZ) where most offshore wind installations are being built. However, the site development plan (BSH, 2020) gives the requirement to minimise emissions as much as possible. So far, the structural security measures for applications involving high amounts of liquid operational materials need to be ensured on an individual basis. A specific guideline including security measures and best practice for handling of hazardous substances specifically for the application on offshore wind structures could ensure to limit the risk of accidents or spillage due to structural measures.

All materials applied on OWTs are assigned to closed systems. The reason for this is that the constructions of the nacelle and the tower are considered to be closed structures. Leakages can be collected in collecting trays, but even in the case of the failure of a collecting tray, the leakage should not enter the environment since it remains inside the structure. However, it has been seen that spillage has occurred, due to defective sealings in combination with human failure (e.g. during maintenance work).

Most of the areas on the OSSs or OCPs are also considered to be closed systems. Technical units associated with the purpose of the platform, storage units, operational units, emergency accommodations and repair shops are located within the closed structure or in sealed containers.

The fire extinguishing systems for those closed areas are also considered to be a closed system, since the extinguishing materials are collected within collecting trays and/or transmitted to the sealed sump tank.

4.2.1.2 Operational materials and maintenance materials in open systems

The operational materials assigned to open systems summarises all materials, which are applied in an open circuit. Open systems during the operational phase are present on the OSS or OCP only and are described in the following sections.

4.2.1.2.1 Surface water

Surface water, like e.g. rainwater or cleaning water, is under normal conditions discharged into the sea. However, the drainage of certain areas with higher risk of spilling of oils is connected with an oil-separator. An oil-separator filters contained oil in operational water. The Site development plan (BSH, 2019) limits in Germany the remaining amount of oil in the oil-separator discharge to 5 ppm. In the case of an exceedance of this limit, the discharge is redirected into the sump-tank to prevent higher concentrations of oil to be emitted into the sea. This procedure is automated and controlled via a remote monitoring and control systems (SCADA). The control systems need also to ensure, that in the case of a fire emergency on the helicopter deck or maintenance work with hazardous materials, the mixture of water and extinguishing foam/ drainage water is not directed to the normal drainage system including the oil-separator, but rather redirected to a sump tank via a bypass. The sump tank needs to be designed in such, that the full amount of fire extinguishing liquid of the helicopter deck can be captured additional to a common filling level.

4.2.1.2.2 Seawater extractions and discharge for cooling circuits and freshwater supply

On the OSS and OCP platforms cooling circuits are required for cooling of technical components such as transformers. Further, in some cases the water is used amongst others for sanitary purposes, in the workshop or mixing for firefighting foam. The applied cooling circuits can be implemented by open or closed cooling circuits. Open cooling circuits extract seawater for cooling, while closed cooling circuits are self-contained circuits and cooled via a cooling unit or heat exchangers. According to the German Site development plan (BSH, 2020) closed cooling circuits are preferred over open systems. The permit for an open cooling system during the design phase is only applicable in the case that the required cooling performance cannot be achieved with closed systems.

At this stage, open cooling circuits are present on OCPs and to some extent on old OSS platforms, since the required cooling performance cannot be satisfied with closed cooling circuits. However, there have been new concepts on closed subsea cooling systems for OCPs in Offshore wind (see e.g. FSCC design in Espedal, 2019). The application and long-term experiences of such a system are not known so far.

In the case of open cooling circuits, antifouling measures are needed to prevent marine growth at the sea-water extraction and inside the system. Possible antifouling measures are e.g. the installation of copper-anodes, which produce copper oxide (referring to Cu^{2+}) due to a redox reaction, so called Impressed Current Antifouling Protection System (ICAF) also known as Marine Growth Prevention System (MPGS). The reaction of the copper oxide results in a release of copper ions in very small amounts; referring to Cu^{2+}. Another possible antifouling system is the electric-currents-initiated redox reaction of the natural sea water salt (sodium chlorite) content to sodium hypochlorite, which is functioning as an antifouling solution. The concentration of sodium hypochlorite at the production cell is reduced from the intake of the open system till the outlet. At the outlet, concentrations of 0.1-0.3 ppm sodium hypochlorite are present (Source: emission studies). However, during the production process of sodium hypochlorite a wide uncontrolled range of chloride containing substances may be formed, from which some may have potential PBT properties (Van Hattum et al., 2004). According to a study of the Danish Ministry of the Environment (Escudero-Oñate, 2015), the expected concentrations of sodium hypochlorite in e.g. cooling water treatment are expected to be extremely low. The low concentrations and the high reactivity of the substances indicate that they do not pose and environmental hazard (Escudero-Oñate, 2015). Another possibility for antifouling measures is the application of UV-disinfection as it is used for waste-water treatment described in section 4.2.1.2.3. However, according to López-Galindo (2010), the UV disinfection is not as effective in prohibiting marine growth and merely slows down the process of marine growth.

Antifouling systems are further required for disinfection for fresh water supply, where seawater is desalinated for application purpose at e.g. the kitchen and sanitary facilities.

4.2.1.2.3 Discharge of grey and black water

Platforms like OCPs are frequently accommodated over the year. The presence of people requires a concept for the wastewater treatment of black (wastewater including faecal matter from toilets, etc.) and grey water (free of faecal matter just slightly polluted, such as sewage from showering, bathing, laundries, etc.). There are two main concepts for wastewater treatment: the disposal onshore and the wastewater treatment offshore. In the first case, the wastewater is collected in mobile or static tanks and transported by ship to shore for disposal. In this case, there are no emissions to be expected. However, the transport of wastewater per ship bears risks at challenging weather conditions. Further, the disposal reliability can be terminated in ongoing bad weather periods. The second option is the wastewater treatment on the platform. According to the Site Development Plan (BSH, 2020), sewage treatment plants need to be certified at least by standards of MARPOL MEPC 227(64). This guideline gives limits for e.g. total suspended solids (TSS) amounts, thermotolerant coliforms, biochemical oxygen demand, nitrogen and phosphorus. For the water treatment, different systems can be applied such as a combination of micro floatation and UV-disinfection or an ultrafiltration system (see MARPOL MEPC.227(64)). For kitchen wastewater an oil-separator system/grease trap can be in front of the wastewater treatment stage. Biological wastewater treatment is normally not designed for longer unmanned periods, but these periods can be bridged by usage of nutrient solutions to keep the microbial community alive (YARA, 2021). The solid contents of the treated wastewater need to be reduced to the allowed amounts according to MARPOL and has to be disinfected/freed from most bacteria. The major emissions from the treated wastewater are nutrients which are expressed as total nitrogen (sum of inorganic nitrogen in ammonium, nitrite and nitrate) and total phosphorus.

According to the German Site development plan (BSH, 2020) the collection of grey and black water with a disposal onshore is preferred over the water treatment on platforms. Water treatment systems for un-manned platforms or platforms which are only accommodated during maintenance procedures are in general not allowed. MARPOL MEPC 227(64) aims to reduce the emission of nitrogen and phosphor compounds. The chlorination of wastewater is not allowed, due to the generation of hazardous secondary compounds.

4.2.1.3 Operational materials and maintenance materials in closed systems with higher risk of accidents

The operational materials and maintenance materials assigned to the category "closed systems - higher risk", have a slightly higher risk to emit into the environment by accident due to their application at the outside of the structure, the possibility to enter an open circuit or due to bunkering processes.

4.2.1.3.1 Bunkering

The OSS and OCP require diesel for the auxiliary and emergency generators. To be able to run the station over several days, large amounts of diesel are required. To provide these large amounts, the local tanks are refuelled via bunkering process from a tank vessel. Thereby, the diesel is pumped via hoses into the diesel tank. However, the bunkering procedure in an environment as the open sea is not without risks. For this reason, several safety measures are in place to prevent spilling of fuel into the environment. However, since this fuel is mostly not provided in sealed containers as it is for other operational materials, it is listed with the materials of open systems.

Emergency diesel generators on individual OWTs is prohibited in Germany to reduce the risk of the bunkering process (BSH, 2019). A temporary power supply shall be provided by the generators present on the associated OSS or OCP.

4.2.1.3.2 Fire systems

On structures of the offshore wind industry, different types of fire extinguishing systems are present such as permanently installed systems and handheld extinguishers. Depending on the technical components within a room or certain unit, different extinguishing agents are applied, such as inert gases, mixtures with water, film building materials or powder-based materials. As inert gases mostly nitrogen and CO_2 are applied.

In case of usage, liquid or powder based extinguishing agents are collected within collecting trays and are disposed in the sump tank or appropriate container for the disposal on shore. Since most of the technical components on offshore structures are located within enclosed spaces, the risk of emissions entering the water is low. In case of an accident on the outside area such as the top deck of an OSS/OCP, extinguishing material (ABC powder) from handheld devices might end up in the water.

A more critically assessed scenario is the activation of the fire-system on the helicopter deck on the OSS or OCP. On the helicopter deck, the presence of kerosene and the possibility of hydrocarbon flammable liquid fires make the application of a film building material necessary. The applied film floats on the surface of most hydrocarbon fuels and suffocates the fire. As film building material AFFF (Aquatic film forming foam) foams are widely applied. Those AFFF foams often include PFAS materials (per- and polyfluoroalkyl substances), which can be further distinguished into substances belonging to the families of PFOS (perfluorooctane sulfonate), PFOA (perfluorooctanoic acid), PFNA (perfluorononanoic acid) and PFHxS (perfluorohexane sulfonic acid). The EU directive 2019/1021 prohibits the application of extinguishing agents, which include PFAS materials over a certain limit (EU Directive 2019/1021). For PFOS substances the concentration needs to be equal to or below 10 mg/kg if present in substances or mixtures. For PFOA and any of its salts, the concentration needs to be equal to or below 0.025 mg/kg when present in substances or mixtures, while for PFOA related compounds the concentration limit is given to 1 mg/kg. An acceptation is made for PFOA, as its salts and compound can be used in firefighting foams for liquid fuel fires. The application of those is allowed till 4th July 2025 under the restrictions, that those materials are not used for training or test purposes and it can be ensured, that all released materials can be contained.

A recent study of the European Commission and the European Chemical Agency (ECHA) investigated the use of PFASs in firefighting foams and alternatives to PFAS-containing firefighting foams (EU/ECHA 2020). In this study, an overall assessment of the technical feasibility, economic feasibility and availability of seven alternatives for PFASs was undertaken. The results of the study showed that alternatives are generally available, technical feasible and have already been implemented by many user sectors identified. However, efficiency and safety of fluorinated *versus* fluorine-free fire fighting foams is currently highly debated. Thereby, the discussions about AFFF and FFF (Fluorine Free Foams) are very confusing for all parties, concerned consumers, authorities and manufacturers (EUROFEU, 2019). The balance between safety and protection of lives and property and the potential risk to the environment is delicate. According to EU/ECHA (2020), IPEN (2017) and environmental protection associations, FFF are viable alternatives AFFF. However, there is no consensus to approve that FFF meet all needs encountered by end users. LASTFIRE, a consortium of international oil companies, performed many specific tests on various kinds of firefighting foams. LASTFIRE concludes that "*as yet, no commercially available fluorine free foam has shown the same level of consistency or high performance that had become the norm with good quality Multi-purpose AFFFs or fluorine protein foams*" (Lastfire, 2017). In the study of Yu et al. (2020), the conclusion was drawn, that the adverse effect of oil on the stability of AFFF is much less than that of FFF. However, the authors state that „By adjusting the foam expansion ratio, the fire extinction performance of the fluorine-free foam can be comparable to that of the fluorinated foam, and the burnback performance is significantly enhanced" (Yu et al.. 2020). The application of fluorine free alternatives, even for challenging applications e.g. on airports or refineries, where large amounts of liquid fuels are stored have been documented, e.g. from the Danish royal air force (IPEN, 2018) or some refineries with large storage tanks in Norway (IPEN, 2019).

According to the site development plan 2020 (BSH, 2020), PFAS containing firefighting materials are excluded from their application on offshore helicopter landing areas.

In a fire emergency, the mixture of foam building material and liquid is captured in the sump tank of the structure. Thus, the volume of the sump tank should be designed as such, that all volume of potential hazardous materials in a fire emergency can be captured, additional to common filling levels according to the EU regulation 2019/1021.

4.2.2 Corrosion protection

The offshore structures experience the influence of a very harsh environment. Aggressive salt water, sun exposure, temperature changes and cyclical changing conditions support corrosion at steel parts of the structures. As a result, corrosion is next to fatigue issues the most probably failure and degradation mechanism for steel structures offshore (Price, 2017). Therefore, corrosion protection systems are essential to protect the steel construction against corrosion in the harsh marine environment during their lifetime of approx. 25 years and are an important factor for the long-term stability of the offshore structure. The following three corrosion protection concepts are applied in the offshore environment:

a) passive protection by coatings (e.g. epoxy resins and polyurethane)

b) active cathodic protection systems using galvanic sacrificial anodes (GACP) or impressed current cathodic protection systems (ICCP)

c) corrosion allowances ("thicker steel")

The application of the different concepts is based on the chosen protection strategy and the application location at the structure. The structure parts are associated to three different zones:

1. seabed and underwater zone
2. splash zone (SZ), tidal zone (TZ) and low water zone (LWZ)
3. zone under atmospheric conditions distinguished into a
    a. zone under *external (outdoor)* atmospheric conditions
    b. zone under *internal* atmospheric conditions.

Each zone is associated to a corrosivity category and can be associated to a corrosion protection system using passive or active protection or even both. Especially the splash zone is undergoing the most extreme corrosion category of "extreme corrosivity". This zone is influenced by tidal conditions, waves, sunlight, salt splash, biofouling and floating objects e.g. sea-ice in the Baltic Sea. Corrosion in this zone is extreme due to high chloride concentrations, moisture and changes of pH and oxygen during the wet and dry cycles. Therefore, the steel structures (e.g. the transition piece) is protected by coatings also due to the mandatory colour for these parts of the offshore structure (in Germany: RAL1023) (Kirchgeorg et al., 2018). Further, often a corrosion allowance is applied in this area with cathodic protection below mean water level (Syrek-Gerstenkorn, 2020). In the constantly submerged zone typically cathodic protection is applied in form of galvanic anode cathodic protection systems or impressed current cathodic protection systems for the water exposed steel inside and outside the foundation structures (Syrek-Gerstenkorn, 2020). Steel parts in fully atmospheric conditions are typically protected by coatings.

4.2.2.1 Coating

Coatings need to withstand extreme conditions offshore in the individual corrosivity zones. According to the VGB Standard Corrosion Protection Part 2 (VGB, 2018b) the coating requirements include strong adhesive characteristics, resistance against impacts, resistance against water immersion through water, humidity or salt splash spray, sun radiation and cyclic influences of the previous besides abrasion resistance and colour authenticity. Coatings are typically applied in areas exposed to the marine atmosphere as well as in the splash/tidal areas (Syrek-Gerstenkorn, 2020). Protective coatings can be divided in four types:

1. inorganic coatings (e.g. ceramic, carbon)
2. organic coating (e.g. epoxy, polyurethane)
3. organic-inorganic hybrids
4. metallic coatings

While the first three type of coatings represent a passive protection with barrier effect, the metallic coatings have further an active component of cathodic protection. According to Prince (2017), the most commonly applied coatings for offshore structures are organic and very recently in the offshore wind industry also metallic coatings or rather a combination of both (TWI, 2018).

4.2.2.1.1 Organic coatings

Price (2017) is giving some example of typical organic coating systems for individual exposure zones of OWTs. If applied in combination with cathodic protection, the organic coatings need to be designed for this combined application. Based on the corrosivity zone a minimum number of coats (MNOC) and a nominal dry film thickness (NDFT) need to be reached (VGB 2018b).

Epoxy resins (EP) and polyurethane (PUR) based coatings are a state-of-the-art technique for corrosion protection in a wide range of marine applications (shipping, harbours and offshore infrastructures) and are an artificial barrier to separate the steel from the corrosive environment (Kirchgeorg et al., 2018). The coatings are applied onshore on the steel structure, to ensure a sufficient surface preparation and application of the coatings, which is crucial for the performance of the pint system (Prince, 2017). Organic coatings can be applied in different parts of the monopiles where the areas with direct contact with water are the most relevant for potential chemical emissions to the seawater. Different coatings are applied in German Offshore Wind farms. They may consist of a priming layer (e.g. EP-Zn or 1C/2C PUReZn, EP or EP) and 2–4 layers of intermediate or top coatings (EP or 1C/2C PUR) (Kirchgeorg et al., 2018). The number of layers and dry film thickness (up to 700 µm or more) of the coating depends on the applied type of coatings systems and which technical standard is referred to. An overview of applied layers in the German wind energy sector can be found in Momber and Marquardt (2018).

Due to abrasion smaller pieces or particles of coatings can be emitted into the environment during the lifetime of an offshore structure. Since the coatings are often based on artificial materials such as polyurethanes, polyacrylates, epoxies or polystyrenes they contribute to the chemical and microplastic pollution although their polymer concentration can be lower than other microplastics (Gaylard, 2021). The amount of microplastic entries emitted from offshore wind structure coatings is probably small compared to the emissions from antifouling coatings of vessels (Gaylard, 2021).

Coatings are applied and harden onshore, which reduces emissions and avoids the release of not fully cured coating material directly into the water. However, it is unknown how frequently coatings are maintained offshore, which might be an additional source of emissions (especially from the application process), but it is difficult to quantify (Kirchgeorg et al., 2018). In the study of Burkhardt (2015), four different epoxies have been investigated after 1 and 7 days of hardening regarding their influences on the ecotoxicology. The materials are declared for the application as cover coating in seawater according to the authorisation lists of the Bundesanstalt für Wasserbau (BAW, Karlsruhe). Depending on the tested product various toxic effects could be observed including hormonal effects related to Bisphenol A (BPA). Similar effects have been observed in the study of Vermeirssen (2017) and Bell (2020a). Bell (2020a) identified 4tert-butylphenol as a hardener in epoxy resins as the main contributor to acute and estrogenic effects and recommends replacing the substance by higher molecular weight phenols. However, the observed effects in these studies under laboratory conditions are going to be diluted under real applications and actual toxic effects cannot be derived from this study (Burkhardt, 2015). Further, the coating of offshore structures is performed onshore, thus the hardening of the coating is not taking place in the aquatic environment.

Kwon (2017) state that assuming the level of plastic particle density in the open ocean, the resulting concentration of additives in water or other environmental media is likely to be extremely low and will therefore not pose a risk to marine organisms. According to the modelling work of Koelmans (2016), the risks associated with leaching additives in plastic (BPA and nonylphenol) in plastic ingestion was negligible for fish and may occasionally be relevant for marine worms and therefore are not likely to constitute a relevant exposure pathway.

4.2.2.1.2 Metallic coatings

Metallic coatings with a cathodic protection effect are based on aluminium or zinc particles applied on the steel surface. The application on the steel surface takes place via e.g. thermal spraying (TSA – thermal sprayed aluminium) or cold spraying. Metallic coating for OWTs are recently tested in the CROWN project (Cost reduction of offshore wind now – TWI, 2018) and have been applied in combination with an epoxy top coating at the Arkona windfarm in the Baltic Sea (Syrek-Gerstenkorn, 2020). Depending on the applied anode metal, the metal coating release aluminium (TSA) or zinc (TSZ) into the aquatic environment. Emissions from the TSA aluminium coatings, assuming a mass reduction of 90% over the structure lifetime, is identified to 38 kg/year per foundation for an exemplarily windfarm.

4.2.2.2 Cathodic protection

Cathodic protection systems are the most commonly used active corrosion protective techniques for all kinds of steel-constructions like ships and infrastructures in marine and harbour environments. Through the supply of current, a permanent reduction in potential is achieved to slow down the oxidation processes. The protective current can be generated by galvanic "sacrificial" anodes or ICCP systems. Those provide the protection current for the polarization of the metal surface by either the galvanic reaction of a less noble material compared to the steel structure (GACP) or the active current (ICCP) (Kirchgeorg et al., 2018). The cathodic protection can be applied alone or in combination with a suitable coating on the steel structure. However, the application of sacrificial galvanic anodes is just permitted with appropriate coating suited for galvanic protection (BSH, 2015). ICCP system are the preferred cathodic protection system, since it does not associate the emission of large amounts of metals contrary to galvanic anodes (BSH, 2020). For complex structures also hybrid systems are applied, combining ICCP and galvanic anodes. Thereby, galvanic anodes are placed in areas, so called shadow zones, where no sufficient protection by ICCP can be provided (Source: Emission concepts of individual windfarms).

4.2.2.2.1 Sacrificial/galvanic anodes

For offshore structures aluminium-based galvanic anodes are preferred and mainly used. No example of zinc anodes applied on German OWF has been found in this study, which might be related to the restrictions of BSH to limit the amount of zinc to a minimum. However, zinc cannot be excluded completely, since it is necessary for activation and to avoid passive oxide films on the anode surface (Kirchgeorg et al., 2018). The resulting variance in composition based on the windfarms investigated in this project is resulting from small differences in the composition of metals per anode per windfarm and per structure (OWT/OSS/OCP).

Table 2 shows an overview of the composition of aluminium anodes normally used in offshore applications for the European Standard EN 12496:2014 and the NORSOK standard M503 (2007). Alternative information is given also in DNV-RP-B401(2010) and ISO 15589-2 (2012), which give similar compositions. Further, the composition of metals found during the analysis of the different wind farms in this project is presented in Table 2. The variance in composition based on the windfarms investigated in this project is resulting from small differences in the composition of metals per anode per windfarm and per structure (OWT/OSS/OCP).

Table 2: Chemical composition of aluminium anodes according to EN 12496:2014 and NORSOK M503.

Metal	Mass percentage (%)		Mass percentages (%) found in this study
	EN 12496:2014	NORSOK M503	
Aluminium	94.1-96.6	93.8-97.1	93.5-96.6
Zinc	3-5.5	2.5-5.75	4-6.5
Indium	0.016-0.040	0.015-0.040	≤0.04
Iron	≤0.09	≤0.09	≤0.13
Silicium	≤0.12	≤0.10	≤0.12
Copper	≤0.006	≤0.003	≤0.01
Cadmium	≤0.002	-	≤0.002
Other impurities (each)	≤0.02	-	
Other impurities (total)	≤0.1	≤0.02	

However, the comprehensive investigations of Reese (2020) showed, that there are significantly more metal compounds within sacrificial anodes than described in the official standards. Thus, for the widely applied aluminium anodes in total 25 other metals have been found. Amongst other, lead and gallium has been found to be included to similar amounts as indium and cadmium.

According to Bell 2020b, aluminium anode material does not cause acute toxicity on the tested marine organisms of bacteria, algae or amphipods at the concentrations which are expected to be released during cathodic protection at offshore wind structures. However, long-term or accumulative effects like the trophic transfer of metals within the marine food web remain uncertain and therefore cannot be ruled out (Bell 2020b). From the metals that were identified in the investigated structures indium, cadmium and mercury are listed as possibly hazardous substances to the marine environment at high concentrations. Additionally, copper is currently being assessed for its potential as an endocrine disruptor (ECHA, n.d. c). Although lead was not identified in the investigated structure, Reese (2020) found similar amounts of lead in sacrificial anodes as compared to copper. Lead is known as toxic and environmentally critical. Other metals identified by Reese (2020) are shown in Table 3, including the mean emission (g) per lifespan (27 years) and the calculated mean emission per year (kg/year) for the protection of a coated monopile foundation in seawater by 2164 kg aluminium galvanic anode. The metals identified by Reese (2020) are not identified in the investigated structures. However, there are chances that these substances are present in the investigated structures (OWT/OSS/OCP) in very low amounts. Reese (2020) estimated the emission from these metals as being equal to or lower than 0.05 kg/year. The composition of additional metals in aluminium anodes may vary and it is impossible to estimate the expected emission from additional metals from the investigated structures based on the paper by Reese (2020). Therefore, additional metals cannot be further discussed.

Table 3: Overview of estimated emissions of other metals from Reese (2020) for the protection of a coated monopile foundation (extraction of mean emissions > 10 g over 27-year lifespan)

Substance	Mean emission (kg) over 27-year lifespan	Calculated mean emission (kg/year)
Manganese	1.300	0.05
Bismuth	1.400	0.05
Gallium	0.220	0.01
Vanadium	0.250	0.01
Nickel	0.083	0.003
Potassium	0.026	0.001
Lead	0.018	0.001
Magnesium	0.011	0.0004

To get an overview on the emissions due to galvanic corrosion protection for various windfarms, calculations were performed in this study to determine the emissions per offshore structure (OWT, OSS and OCP) per year. Based on the mass percentages defined in the anode composition, the total mass of the anodes and the expected lifetime of the anodes and the assumed current density, the amounts of metals emitted into the environment can be calculated. The waste- and operational materials concepts and emission studies of the permitting procedure of individual windfarms provided by BSH were consulted to determine the total mass of anodes and the expected lifetime. The anode composition was thereby limited to information on metals which are defined by selected available standards (see Table 2). The expected lifetime of the anodes varies slightly between 25-30 years. In the calculations a 90% mass reduction of the original anode mass is assumed.

In Table 4,

Table 5 and Table 6 the metal emissions per windfarm for the individual structures are shown. Only windfarms with galvanic sacrificial anodes are included in these tables. The amount of anode mass required for an individual structure is based on the surface area which requires corrosion protection as well as the local environmental conditions. Since most sacrificial anodes are aluminium based, aluminium represents by far the highest emission of metals. Per OWT the emissions of aluminium range between 38 and 681 kg/a. Due to the higher surface area of offshore platforms like OSS and OCP, sacrificial anodes can result in emissions up to 3326 kg/a for those structures.

Table 4: Overview of emissions for all OWT structures per windfarm with sacrificial anodes.

OWT	Life-time	Emission per OWT (kg/year)							
Windfarm	Years	Aluminium	Zinc	Indium	Cadmium	Silicon	Iron	Copper	Mercury
1		200							
2	27	67	4	0.03	0.001	0.1	0.06	0.002	
3	27	100	7	0.03					
4	27	398	28	0.1					
5	25	148	7.8						
6	25	38							
7	28	277	12	0.09		0.3	0.3	0.001	
8	25	681	35		0.01		0.4	0.02	0.1

Table 5: Overview of emissions for OSS structures per windfarm with sacrificial anodes

OSS	Life-time	Emission per windfarm (kg/year)						
Windfarm	Years	Aluminium	Zinc	Indium	Cadmium	Silicium	Iron	Copper
OSS 1	27	846	52	0.4	0.02	1.1	0.8	0.03
OSS 2	27	890	62	0.3				
OSS 3	25	897	47					
OSS 4	25	928	49					
OSS 5	28	1426	67	0.3		1	2	0.1
OSS 6	25	1241	79				158	7

Table 6: Overview of emissions for OCP structures per windfarm with sacrificial anodes

OCP	Life-time	Emission per windfarm (kg/year)						
	Years	Aluminium	Zinc	Indium	Cadmium	Silicium	Iron	Copper
OCP 1	30	3326	139	1.4	0.07	4.2	3.1	0.1

Sacrificial cathodic protection systems should not be installed internally in completely sealed structures such as monopiles (Delwiche et al., 2017). The chemical reaction of sacrificial anode systems can cause an acidification of the internal water from the natural pH value of 8 to values below 5 after a few weeks (Delwiche et al., 2017). This drop in pH value can cause damage to sensitive cables and other fitting inside the monopile and also accelerates the consumption of the anodes itself (VGB 2018d). Additionally, hydrogen sulphide and carbon monoxide gasses are emitted. To prevent an acidification of stagnant water e.g. replenishment holes can be foreseen at the steel design phase, to ensure a sufficient replenishment of the internal water due to tidal currents and waves.

4.2.2.2.2 Impressed current cathodic protection (ICCP)

Impressed current cathodic protection is an emerging technique in offshore wind farm construction that actively protects the submerged zones from corrosion and is already used for ships and water waterways infrastructure (Kirchgeorg et al., 2018). According to VGB (2018d) the following ICCP systems have proved themselves in seawater conditions:

- metal oxide coated titanium (MOX), high specific current density
- magnetite anodes, can be used with high driving voltages; resistant to acid and chlorine gas
- platinum-coated titanium/niobium/tantalum, high specific current density

These systems have no significant emissions.

However, also ICCP systems should not be applied in a completely sealed environment, since the chemical reaction with the sea water leads to the production of free chlorine and locally low pH values (Duncan (2016), VGB/BAW Standard (2018d), SP0176-2007-SG).

According to the German site development plan (BSH, 2020), ICCP systems are to be preferred over galvanic anodes, since no large metals emissions are associated with this corrosion protection technique. For complex structures also hybrid systems are applied, combining ICCP and galvanic anodes. Thereby, galvanic anodes are placed in areas, so called shadow zones, where no sufficient protection by ICCP can be provided (Emission concept).

4.2.3 Scour protection

After their installation offshore windfarm structures are interacting with the local marine environment. The local metocean conditions include hydrodynamic processes such as waves and currents. Due to the presence of a structure, flow speeds and turbulence levels can be increased locally around the structure. Since OWF infrastructure is typically placed on soft sediments, this local increase of flow can lead to scouring. The extent of the scour depends on the environmental factors (hydrodynamic conditions, water depth, soil characteristics, etc.) and structural factors (structure design, diameters, etc.). Depending on the extent of a scour hole, this might compromise the stability or dynamic behaviour of the OWF infrastructure. To prevent a reduction of the structure stability in the case the estimated scour is of greater extent, scour mitigation measures are considered in the design process.

In the case scour protection measures are required due to the local environmental characteristics, the most prominent locations for scour protection measures on an OWF are around the foundation of the offshore structures and along the export cables. Versatile scour protection measures exist for offshore applications.

In the German exclusive economic zone (EEZ), stone rubbles are the predominant scour protection method. Thereby, the rocks are installed in layers (single or various layers) on the seabed around the foundation. According to the Site development plan (BSH, 2020), natural stones are the preferred solution for rock protection systems. No hazardous emissions are expected from these natural materials. In contrast to scour protection in rivers or estuaries, there is no literature found on the application of artificial stones (e.g. slags) within the North Sea for offshore scour protection. According to a literature study of Glarou (2020), also world-wide predominantly stone/rock rubbles are applied for offshore scour protection measures around an offshore foundation.

Besides the most common rock protection solutions, also other protection methods are existing such as geotextile sand containers, geotextile stone containers, geosynthetics, nylon mesh bags, concrete mattresses or rubber mats. In the German EEZ geotextile sand containers (GSC) are applied in rare cases for scour protection only (Naue, n.d.). Thereby, geotextile containers are filled with sand till a certain filling degree. The geotextiles are flexible and can adjust its shape to its local position. During the operational lifetime of the scour protection, it is possible, that fractions of synthetic/artificial materials in form of plastic debris or microparticles are released into the environment due to e.g. ruptures or abrasion and can disintegrate through mechanical processes to microplastic. Further, leaching from additives in the geosynthetic materials can occur. However, the entry of plastic in the environment is critical primarily due to the contamination of the environment with the non-degradable plastic itself rather than due to its toxic properties. Investigations on emissions from geotextile leaching are possible. A suitable overview on additives in geotextiles and their ecotoxicology is provided by Wiewel & Lamoree (2016). According to Scholz (2021), ecotoxicological tests did not show significant toxicity of geotextile leachates to water organisms. This is also due to the fact that leached substances are strongly diluted in offshore applications. According to the Site development plan (BSH, 2020), the application of synthetic/plastic materials for scour protection purposes in the German EEZ are forbidden. However, there are new attempts to apply natural materials for the manufacturing of containers, tubes or cages such as coconut or basalt fibres. For cable protection measures at e.g. cable crossings, concrete mattresses are sometimes applied for scour protection measures. Concrete is frequently applied in artificial reef measures. No hazardous dissolvent emissions are expected as long as appropriate concrete for the marine environment is applied.

In the UK more variation in scour protection measures is applied. For example, geotextile stone containers are applied at the OWF Dudgeon along of two 42-Kilometre export cables (Subseaprotectionsystem, n.d. a). The same risks as for GSC are valid for these kinds of scour protection materials. Further, concrete mattresses are applied for scour protection measures at the turbine foundations (e.g. East Anglia (Offshore energy, 2019)) and the export cables (e.g. Greater Gabbard (Subseaprotectionsystem, n.d. b)). In the Scroby Sands wind farm (UK), a trial has been performed with recycled car-tyre mattresses for scour protection along cable connections and around turbine foundations. Thereby, the tyres are connected to a mattress of large extent, to prevent scour over the covered area (Niddrie-Webb, 2018). Since rubber is a synthetic material such as geotextiles, the application as scour protection might lead to abrasion/rupturing of material into the environment. However, the decommissioning of such a mattress requires less effort and offshore time, than the decommissioning of e.g. a rock rubble.

In the Netherlands, the application of natural stone rubbles is the preferred scour protection measure. However, in some cases the installation of an offshore scour protection is accompanied by additional measures to create artificial reefs for different species. Due to those measures, the ecological functioning of offshore scour protection measures should be enhanced. Different scour protections in offshore wind farms can create new habitats to compensate a certain habitat loss due to offshore energy installations. A study of the university of Wageningen, Deltares, TU Delft and Bureau Waardenburg (Lengeek, 2017) aimed to explore the possibilities of eco-friendly designs of scour protection structures around monopiles in planned wind farms to enhance ecological functioning. Therefore, the suitability and sustainability of different scour protection materials for artificial reefs are discussed. Lengkeek (2017) provides an overview of materials used and potentially suited for scour protection systems on offshore structure as a habitat for marine species including several images of the individual protection systems.

4.2.4 Cables

During their operational life, subsea power cables are not expected to be a relevant source of contaminations. The materials in the outer layer of the cable are mechanically resistant and chemically unaffected by the sea water (Ardelean, 2015). However, in the case of a cable damage or degradation, the inner cable components can become a source of contamination.

In the case of cable deterioration, metal components might become exposed, which might release heavy metals in the environment (Meißner, 2006). Examples are the copper conductor, sheaths made from lead or other metals. The heavy metals might leach into the sediment, in which the cables are buried. According to Schreiber (2004) an amount of 12 kg lead/m is present for a 3.5 mm thick lead sheath. Another source of potential emission due to deterioration is the insulation. While the commonly applied insulating materials of mass-impregnated paper or cross-linked polyethylene are high-density substances that remain stable for ionic change in the salty water environments (Ardelean, 2015), fluid insulated cables can be a source of contamination. In the case of a cable breakage, insulating fluid might enter the environment (Taormina, 2018). Depending on the time till the damage is recognised, the repair time, the damage extent and its location, several 1000 litre of liquid can be emitted into the environment (Meißner, 2006). However, according to our knowledge fluid insulated cables are an older type of cable and not applied in offshore wind power transmission in the North or Baltic Sea. Applied insulating fluid are mineral or synthetic oils such as e.g. linear alkylbenzene fluids. According to ECHA, linear alkylbenzene fluids compounds are not PBT or vPvB, and there are no concerns for the environment or human health.

Under normal circumstances cables should be always buried or covered. However, due to morphodynamical activities, failure of scour protection or human error cables might get exposed over their lifetime. In this case, the cables are not sufficiently protected, and abrasion of the outer sheath materials can occur. The sheath consists of artificial materials such as polypropylene, polyurethane or bituminous compounds. The materials used for the sheath can be released into the marine environment due to abrasion from exposed cable sheaths in the form of e.g. polymeric particles.

4.3 Possible emission sources of hazardous substances during Decommissioning

At the end of the operational lifetime the structures are repowered, converted or decommissioned. The phrase of repowering is originating from the onshore-wind sector and describes the refurbishment or complete replacement of a wind-turbine (Weidmann, 2016). Since the offshore-wind sector is still a young type of industry, the experiences on the procedure at the end-of-life of an offshore-wind structure is limited (Topham, 2019). Due to the rapid development in rotor size and associated monopile diameter, it is unlikely that turbines are going to be refurbished, since more efficient and larger turbines are going to be available. More likely, the old turbines are going to be decommissioned and recycled while completely new structures are installed instead. On the site of the offshore platforms such as the OSSs or OCPs, the experiences from the offshore oil and gas industry can be applied. So, it is common practice, to deinstall the whole topside of the platform after deinstallation of the well and production risers and to recycle the topside onshore.

However, it is of special interest to which extent the fundaments of the structures are going to be decommissioned. The term decommissioning regarding fundaments is widely used for cutting off the support structure beneath the water line, near the bed level or even the complete deinstallation of the support structure from the ground. According to Topham (2019), in the time between 2020-2030 a total of approximately 1800 offshore wind turbines needs to be decommissioned in European waters, whilst this number increases between 2030-2040 to already 22000 turbines assuming that the turbines indeed reach their planned service lifetime. The discussion between a total and partial removal is especially controversy from an environmental view, since the removal of fundaments, scour protection and cables can lead as well to a significant disruption of the habitat (e.g. Smyth (2015) and Statoil (2014)). According to the site development plans of the BSH (2020), a complete decommission of offshore structures can be refrained if the decommission results in more negative effects for the environment than the remains of the structures offshore, but only as long as the decommission is not required for safety or ease of shipping traffic. Nevertheless, the structure needs to be decommissioned as such, that the top side of the fundament is below the sediment surface and below the working extent of fishing equipment.

4.3.1 Foundations

The support structure of the foundation is embedded deep into the ground. For this reason, the complete removal of the embedded structure parts is difficult since extensive retaining forces such as surface friction needs to be overcome. Potential methods for a complete removal are e.g. vibration or overpressure extraction; see e.g. Elkadi, 2020. Nevertheless, the extent of the removal of the foundation is discussed controversially, as mentioned above. A partly removal might be sufficient to ensure e.g. the safety and efficiency of ship traffic. In any case, the Site development plan (BSH, 2019) gives the partial removal of the foundation till below the sediment as the minimum requirement. A sufficient covering of the remaining parts needs to be ensured. The cutting is performed by e.g. abrasive water jets or diamond wire saw. In the case of abrasive water jets, a suspension of water and e.g. hard rock particles is applied to reach high cutting performance. The suspension is not expected to be a relevant emission, since natural garnet particles are applied. The remaining steel parts of the foundation are not expected to be a relevant source of emissions.

4.3.2 Scour protection

The site development plans of the BSH (2020) state that a complete decommissioning of offshore structures can be refrained if the decommissioning results in more negative effects for the environment than the remains of the structures offshore. It has been seen, that around scour protection measures, marine life is flourishing over time. Thus, it needs to be determined, if the removal leads to more significant impacts on the environment than the remain (Topham, 2017). An option might be also the reuse, an adaption of existing scour protection for repowering.

As stated in section 4.2.3, the effort of scour protection removal depends e.g. on the local seabed dynamics, the water depth and the applied materials. Over its lifetime, as scour protection measure can be fully covered by soil material due to e.g. sand dune movements, which complicates the complete removal of the protection measure. The different scour protection measures also lead to different efforts and problems for the decommissioning. While the effort to clear a rock rubble is logistically more intense, the decommissioning of GSC is easier due to its greater dimensions per piece. Since synthetic materials also age over the operational lifetime of an offshore structure the decommissioning might result in ruptures and artificial materials remain in the environment. Further, the artificial material needs to be disposed in high amounts. The operational time of vessels is increasing with increasing effort of the scour protection decommissioning, Thus, possible emissions due to ship assignments will be higher for materials which require a higher effort of decommissioning. However, the emission of substances or particles of the scour protection itself is expected to be not different from eventual emissions discussed in section 4.2.3.

4.3.3 Cables

The decommissioning of cables is highly recommended, to prevent contaminations as presented in section 4.2.4. During the decommissioning concept of buried subsea cables, sediment can be mobilised. In the case of contaminated sediment, hazardous substances can be emitted into the aquatic environment. These risks are equal to those during the installation phase, presented in section 4.1.3. In the German EEZ the decommissioning of cables is stipulated in the approval (OSPAR, 2012; BSH, 2019).

5 Resulting operational material and substance lists

5.1 Operational material lists

Two sets of operational material lists are compiled within this study. The first set includes the operational materials on the offshore structures which are identified in section 4.2.1. This operational material list is distinguished by the structure type into one list for OWTs, OSSs and OCPs respectively. The second set contains the materials associated to the corrosion protection identified in section 4.2.2. In the corrosion protection material list, all individual structure types in offshore wind farms (OWT, OSS and OCP) are summarised in one list (see Section 5.1.1). Materials which are not identified as operational material or corrosion protection are not separately presented as a list but were already identified within the associated subsections of section 4.

5.1.1 Structure and content of operational material lists

The operational material lists provide information on the specific name, the location and purpose on the offshore structure of the material and the material specification. Furthermore, diverse sub-categories are defined (see Figure 8 and Figure 9). The operational materials lists contain confidential content, which cannot be published or anonymised and can therefore not be included to this report.

Figure 8 presents the subcategories (as headers) associated to the materials location. First, the lifecycle is given, which is associated to the material application. In most of the cases the material is associated to the operational phase, but for some materials the phase of maintenance is given, if it is stored for maintenance purposes. Under “Usage” the material is associated to a certain material category and the specific purpose is given. The predefined material categories are: antifreeze, batteries, coating, coolant, epoxy, fire protection, fuel, gear oil, glue, grease, hydraulic oil, insulating gas/liquid, lubricant, transformer oil, other machine media or other material. To give an impression on the material location, first the structure unit is given (e.g. nacelle, tower on the OWT or e.g. cable deck, top deck on the OSS and OWP), further the location within the unit (room number or name) as well as the specific location such as the system or the technical component in which the material is applied (e.g. tower damping system, gearbox, transformer). Further, the material is associated to an open or closed system in the case the required information to determine this information are given.

Figure 8: Operational material list header on material location

		Location Material						
Nr.		Lebensphase	Verwendung/Usage		Standort	Einsatzort	Bezeichnung	inside/out side
No.	Name	Lifecycle	Category	Specific	Offshore Unit	Location on unit	Specific Area	open/ closed

Source: Deltares 2022

Figure 9 presents the subcategories (as headers) on the material specifications. First, the supplier of the material as well as the material state (e.g. gas, liquid, paste) are given. Second, the mass or volume of the material is presented. Be aware., that the amounts given for the operational material are based on total amounts, which are present on an offshore structure according on the investigated waste- and operational materials concepts and emission studies.

The amounts give no insights into the actual consumption per year. Further, the CAS, H-phrases and P-phrases are specified. Information on dangerous goods class and water hazardous class have been given rarely in the waste- and operational materials concepts. Thus, those are specified only in those cases where the information was directly given.

Figure 9: Operational material list headers material specification

Material specification								
	Zustand	Menge*	Einheits-größe	CAS	H-Sätze	P-Sätze	Gefahrgut klasse	Wasser-gefährdungs-klasse
	State	Volume	unit size		H-phrases	P-phrases	dangerous good class	Water Harzardous Class

Source: Deltares 2022

Not for all operational materials the associated CAS numbers, H- and P-phrases have been included in the waste- and operational materials concepts. In case there was no information given, the related Material Safety Data Sheet (MSDS) has been assessed. In the cases that there was no MSDS available, the supplier's website or other internet sources have been searched for the MSDS. The CAS numbers defined in this way are marked blue in the operational material list. If this process was not successful, the given information of the other windfarms has been investigated by cross referencing the MSDS. The CAS numbers defined in this way are marked green in the operational material excel list. If a MSDS could be related to a certain operational material, a link to the location of the MSDS is given in the list.

In the case a material is applied at different locations within the same offshore structure, the locations are summarised under a data outline, which can be grouped or ungrouped via the plus/minus sign at the left edge of the list. For each subcategory of the operational material list a filter function is activated. Thus, the list can be searched via filters.

Besides the operational material list, also a corrosion protection list was developed. Just as the operational material list, the corrosion protection list contains confidential information, which is not agreed to be published or anonymised and are therefore not included in this report. The corrosion protection list contains information on active and passive corrosion protection measures. As in the operational material list, first the location of the protection measure is given. The location is specified by the structure type, the offshore unit (e.g. foundation, transition piece) and the specified location (e.g. splash zone, below depth). The structure type needs to be defined, since all wind farm structures and OWPs are summarised in one list. Furthermore, the usage is defined by a category and a specific application. The specified categories are sacrificial anodes, ICCP, primer, coating, epoxy. The possible emissions, which are associated with the identified corrosion protection measure, is given under the next header section. Thereby, the kind of emission (chemical, abrasion), the emitted substance and the prognosed emitted amount over the operational lifetime is defined.

Figure 10: Corrosion protection list headers

Location protection					Possible emission			
Bauwerk	Verwendung/Usage		Standort	Einsatzort	Emissions weg	Substance	Eintragsmenge	
Structure	Category	Specific	Offshore Unit	Location	Kind of emission	Substance	Emission amount	

Source: Deltares 2022

In the case of passive corrosion protection, the material name and material specifications are given. However, as described in section 4.2.2.1 the coatings are not expected to lead to emissions, since the materials are not chemically reactive anymore after application on shore.

5.1.2 Results of operational material lists

The operational materials give detailed insights into the applied operational materials and in some cases storage materials.

The analysis for the **operational materials applied on the OSS/OCP** showed the highest amounts of materials for the following material categories:

- diesel (fuel for emergency generators)
- transformer oils / insulating oils (e.g. for the transformers, switchgears)
- hydraulic oils (applied in cranes e.g. at the top deck)
- gear oil (e.g. for emergency generators)
- coolants
- AFFF foams (firefighting on the helicopter deck)

Thereby, the transformer oils, gear oils and coolants are all applied in closed rooms and, thus, associated to the “closed system” category. In contrast, diesel, AFFF foams and gear oils are associated to the category “Closed system with higher risk for accidents” due to risk at the bunkering process (diesel) or the application in open space (e.g. top deck) of the OSS (Gear oil in crane and AFFF foam at helicopter deck.

The **operational materials applied on the OWT** are used in operation only and no storage materials are present. The majority of the operational materials are applied in the Nacelle. Just a few operational materials are present in the tower e.g. in the damper system or firefighting materials. The following material categories resulted in the greatest amounts of operational materials present on an OWT:

- gear oils (e.g. gearbox, azimuth drive)
- transformer oil/insulating oil (e.g. transformer)
- hydraulic oils (e.g. rotor break, rotor lock, azimuth break, generator, blade adjustment)
- coolants (e.g. drive train, E-unit)
- grease (e.g. bearing, azimuth and rotor adjustment, gearbox)
- antifreeze (not present on all OWT)

All applied materials are associated to the category of a “closed system” as explained in section 4.2.1.1.

However, the amount of operational materials does not give information about the amount of individual hazardous substances within the operational materials. Thus, the hazardous substances and the percentual amounts in an operational material need to be identified first. The hazardous substances are presented in the Section 5.2.1.

5.2 Individual substances applied in the offshore wind industry

The individual substances of each operational materials have been identified and analysed as described in section 3.3. The analysis showed that substances are applied in the offshore wind industry, which can either be are shortlisted as hazardous (see Section 5.2.1), while others are harmless (see Appendix A). This section gives an overview on the results and presents the hazardous substances identified and associates them to the application, structure and lifetime phase of the offshore structure (see section 5.2.1). To allow the association between the individual substance and its application in an operation material linking tables were established. However, this information is only confidential and such tables are only used in internal processes of organisations. The linking tables enables the distinction between hazardous substances with no potential risk to the environment and hazardous substances with a risk to the environment. Since the linking table provide a link between the individual substances and the operational material lists, they contain confidential information, which is not allowed to be published or anonymised. Thus, the linking table is not presented in this report.

5.2.1 Hazardous substances with a risk to the environment

Section 3.3 introduced the identification scheme of hazardous substances within this study. Based on the flow diagram in Figure 7 the hazardous substances are identified by various characteristics. The resulting list of hazardous substances is presented within this section. The resulting substances are presented in three tables of hazardous substances distinguished by the system category: hazardous substances used in open systems (see Table 7), hazardous substances in closed systems with a higher risk of accidents and incidents (see Table 8:) and hazardous substances used in closed systems (see Table 9).

The tables include additional information on the associated operational material in which it has been identified. Since not all chemicals are emitted via operational materials but e.g. by direct emission from sacrificial anodes, for some substances this field is blank. Next to the operational material, the volume or rather mass of the associated operational material is presented. If the amount differs per windfarm, a range is given for the open systems and closed system with a higher risk of accidents in Table 7 and Table 8, while for the remaining substances identified in closed systems the individual occurrences are presented instead of a range in Table 9. To calculate the volume/mass of the individual substance, the percentage of the substance within the operational material given in the MSDS is multiplied by the volume (range) of the operational material. The substance volumes are given for the hazardous substances on open systems in Table 7 and closed systems with a higher risk of accidents in Table 8 only. Due to the high number of substances in closed systems, the substance mass is determined only for the substance of interest, defined further in Section 5.3.1. Be aware., that the amounts given for the operational material and associated substances are based on total amounts, which are present on an offshore structure according on the investigated waste- and operational materials concepts and emission studies. The amounts give no insights into the actual consumption per year. Besides the associated operational material and the amounts, the substance tables give information about the decisive criterion which identified the substance as hazardous. If the identified substance is listed on one of the substance classification lists described in section 3.3, the list is stated in the table. If no list is mentioned, the substance does not occur on any lists. Further, the table shows if PBT characteristics have been identified. If no information on PBT is given, then the PBT assessment does not apply for the substance. Most substances could be associated to a H-phrase.

5.2.1.1 Hazardous substance lists for open systems

As described earlier in this report substances used in open systems are of biggest concern as these substances are emitted into the environment directly, this class of substances is regarded as being of the highest risk to the environment. Table 7 lists 11 substances from sources in open systems. It can be seen that none of these substances fulfils PBT/PB/PT criteria.

Five of these substances (cadmium, copper, indium, mercury and zinc) are metals associated to sacrificial anodes, which are emitted slowly over the lifetime of the offshore structure while the anode breaks down. Cadmium and mercury are listed in Annex 8 of the German Ordinance on the Protection of Surface Waters (priority substances under the Water Framework Directive) and as chemicals of priority action by OSPAR. Copper and zinc are listed in Annex 6 of the German Ordinance on the Protection of Surface Waters (river basin specific pollutants). More information on the amounts of metals emitted from sacrificial anodes has been presented in section 4.2.2.2.1.

Furthermore, antifouling measures lead to emissions of hazardous substances through open systems in the form of sodium hypochlorite or copper oxide, depending on the applied system.

Another source of hazardous substances are coatings, which can emit bisphenol A from leaching. More information on this has been provided in section (4.2.2.1).

Further, wastewater treatments can lead to constant small emissions from phosphorus. The only emissions in open systems originating from materials summarised in the operational material lists are Orange oil , sweet, ext. and Stoddard solvent (see Table 7). The first substance is associated to a marine degreaser and has been applied on an OCP in the North Sea. However, it is a maintenance material and is just applied if necessary, during maintenance work. The second substance is associated to an operational material, applied during the installation phase of the OWTs for the sealing of a flange connection between a monopile and a transition piece.

Table 7: List of identified hazardous substances in open systems

CAS nr[1]	Substance	Material category	Volume/mass operational material	Volume/ mass of substance	PBT criteria[2]	Occurrence on substance classification list
80-05-7	Bisphenol A	Leaching from coatings	No information		No	OSPAR list of possible concern, endocrine disrupting substances ECHA, SVHC
7440-43-9	Cadmium	Sacrificial anodes	See report section 4.2.2		-	SIN-list, SVHC, OGewV , OSPAR chemical of priority action
7440-50-8	Copper	Sacrificial anodes	See report section 4.2.2		-	OGewV
1317-38-0	Copper oxide	Antifouling (ICAF)	No information		-	-
7440-74-6	Indium	Sacrificial anodes	See report section 4.2.2		-	-
7439-97-6	Mercury	Sacrificial anodes	See report section 4.2.2		-	SIN-list, OGewV, OSPAR chemical of priority action
8028-48-6	Orange oil, sweet, ext.	Other	40 L	4-12 L	No	-
7723-14-0	Phosphorus	Wastewater Treatment	No information		-	-
7681-52-9	Sodium hypochlorite	Antifouling	No information		-	-
8052-41-3	Stoddard solvent	Other	0.54 m3		No	-
7440-66-6	Zinc	Sacrificial anodes	See report section 4.2.2		-	OGewV

[1] CAS numbers represent a unique numerical identifier assigned by the Chemical Abstracts Service

[2] PBT criteria according to REACH Regulation; “-“ assigns the absence on PBT information; “No” depicts the no PBT criteria according to the REACH regulation

5.2.1.2 Hazardous substance lists for closed systems with a higher risk for accidents

Substances associated to the category of closed systems with a higher risk of accidents are applied in a closed system. However, due to the transport or the location of application there is a higher risk for them to be emitted to the environment through an accident. Table 8 lists the hazardous substances associated to this category. It contains 6 substances within 16 different operational materials, whereby none of it fulfils PBT/PB/PT criteria.

The most operational materials with hazardous substances in this category are for firefighting material. Thus, fluor-surfactants are present in 4 different AFF foams (see section 4.2.1.3.2) and 3 AFF foams include sodium decyl sulphates. According to the waste- and operational materials concepts of the permitting process of different wind parks provided by BSH, the AFF foams including hazardous substances are applied in 6 of the investigated 9 wind parks on the OSS. Further, hazardous substances in AFF foams have been identified on one OCP, whereby there was no information available on firefighting equipment for the other investigated OCP structures.

Another registered substance is naphtalene, present in some diesel and kerosene. While kerosene is just present on one offshore structure, diesel is present on all OSS and OCP structures. However, not every diesel fuel includes napthalene according to the MSDS. Further, Naphthenic acids have been found in 3 products applied on OWT in one wind park in the North Sea, whereby two were grease operational materials and one a gear oil. The grease and gear oil are associated to the category “closed system-accidents”, since they are applied outside at the main access platform at the davit crane. Since, cranes are also present on other OSS structures, it is likely that there are substitutes, which dispense naphthenic acids.

The last two substances like 1,2-benzisothiazol-3(2H)-one and 2-methyl-2H-isothiazol-3-one are associated to one firefighting foam concentrate. This operational material is applied on one OSS only.

Table 8: List of identified hazardous substances in closed systems with higher risk of accidental spilling

CAS nr[1]	Substance	Material category	Volume/ mass operational material	Volume/ mass substance	PBT criteria[2]	Occurrence on substance classification list
2634-33-5	1,2-benzisothiazol-3(2H)-one	Fire protection	240 L	< 0.24 L	No	-
2682-20-4	2-methyl-2H-isothiazol-3-one	Fire protection	240 L	< 0.24 L	No	-
	Fluorosurfactant/component	Fire protection	135 L	0.7-2.7 L		no specific CAS nr
	Fluorosurfactant/component	Fire protection	795 L	No information		no specific CAS nr
	Fluorosurfactant/component	Fire protection	200 L	< 10 L		no specific CAS nr
	Fluorosurfactant/component	Fire protection	400 L / as required	< 20 L		no specific CAS nr
91-20-3	Naphthalene	Fuel	12000 L	No information	No	SIN-list, OGewV
91-20-3	Naphthalene	Fuel	89000 L	< 890 L	No	SIN-list, OGewV
91-20-3	Naphthalene	Fuel	240000 L		No	SIN-list, OGewV
12001-85-3	Naphthenic acids, zinc salts	Grease	67 L		No	-
12001-85-3	Naphthenic acids, zinc salts	Gear Oil	67 L		No	-
12001-85-3	Naphthenic acids, zinc salts	Grease	67 L		No	-
142-87-0	Sodium decyl sulphate	Operation	50 L	2.5-5 L	No	-
142-87-0	Sodium decyl sulphate	Fire protection	200 L	< 10 L	No	-
142-87-0	Sodium decyl sulphate	Fire protection	400 L	< 20 L	No	-

[1] CAS numbers represent a unique numerical identifier assigned by the Chemical Abstracts Service

[2] PBT criteria according to REACH Regulation; "-" assigns the absence on PBT information; "No" depicts the no PBT criteria according to the REACH regulation

5.2.1.3 Hazardous substance lists for closed systems

The list of hazardous substance for closed systems lists all hazardous substances, which are applied in closed systems (see Table 9). Without an accident or human failure, these materials should not be emitted into the water. The list includes 162 applied operational materials which contain potentially hazardous substances. Several operational materials contain the same substances, therefor in total 88 different individual substances have been identified from these 162 operational materials.

From the 88 substances, only one substance was identified as being persistent, bioaccumulative and toxic (PBT) (nonylphenol ethoxylated CAS: 9016-45-9). This substance is also listed on the OSPAR list of possible concern. The substance is applied in hydraulic oil on one OCP structure. The material is applied in small amounts, according to the analysed documents.

Further, two substances were identified as being as persistent and bioaccumulative: dialkyl(C1-C14)dithiophosphoric acid, zinc salt CAS: 68649-42-3 and white mineral oil (petroleum) CAS: 8042-47-5. The first has been found in grease, lubricants, gear- and hydraulic oil. In total 9 different operational materials are found, associated to OWT and OSS structures with partly high amounts. The second PB substance has been found in 7 different operational materials for OWT, OSS and OCP structures, such as transformer oil, hydraulic oil. The operational material containing white mineral oil is often present in high amounts with volumes of the operational material up to 3000 L.

Furthermore, three substances were identified as being persistent and toxic: 2-piperazin-1-ylethylamine CAS: 140-31-8, C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate CAS: 125643-61-0 and phenol, dodecyl-, branched CAS: 121158-58-5. The first has been recognised within a coating of an OWT. However, as explained in section 4.2.2.1 coatings are applied onshore and, thus, are present in liquid form for maintenance purposes only. The second PT substance has been found in two lubricants for OSS and OCP structures. The third PT material is present in three operational materials, such as lubricants. The operational materials, which are present on OSS and OWP structures, are used in volumes of up to almost 700 L.

84 substances have been identified as being hazardous based on their assigned H-phrases. Of 17 substances insufficient data was available to assign an H-phrase, however according to the information available they were identified as being possibly harmful to the environment.

Two substances (phenol, dodecyl-, branched CAS: 121158-58-5 and bisphenol A CAS: 80-05-7) are listed as being endocrine disruptiing according to the ECHA list of Endocrine Disrupting chemicals. Additionally, two substances have been identified as Substance of Very High Concern (SVHC) due to their endocrine disrupting properties, namely nonylphenol CAS: 25154-52-3 and nonylphenol, ethoxylated CAS: 9016-45-9. Thus, in total four substances have been identified as possible endocrine disrupting, but the assessments are still under development.

Table 9: List of identified hazardous substances in closed systems

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
3115-49-9	(4-nonylphenoxy)acetic acid	Other	MM - Closed system	as required	No	-
91273-04-0	1-(N,N-bis(2-ethylhexyl)aminomethyl)-1,2,4-triazole	Grease	OM - Closed system	0.18 kg	-	-
91273-04-0	1-(N,N-bis(2-ethylhexyl)aminomethyl)-1,2,4-triazole	Other	OM - Closed system	1.8 L	-	-
91273-04-0	1-(N,N-bis(2-ethylhexyl)aminomethyl)-1,2,4-triazole	Grease	OM - Closed system	120 L	-	-
67124-09-8	1-(tert-dodecylthio)propan-2-ol	Hydraulic oil	OM - Closed system	10 L	No	OSPAR list of possible concern
77703-56-1	1,1'-(methylenedi-4,1-phenylene)bis(3-butylurea)	Other	MM - Closed system	0.3 L	No	-
95-63-6	1,2,4-trimethylbenzene	Coating	MM - Closed system	4.4 L	No	-
89347-09-1	1,3,4-Thiadiazolidine-2,5-dithione, reaction products with hydrogen peroxide and tert-nonanethiol	Lubricant	OM - Closed system	0.3 kg	No	-
16096-31-4	1,6-bis(2,3-epoxypropoxy)hexane	Coating	MM - Closed system	No information	-	-
151006-58-5	1-dodecene dimer with 1-Decene, hydrogenated	Grease	OM - Closed system	87-8040 L	-	-
95-38-5	2-(2-heptadec-8-enyl-2-imidazolin-1-yl)ethanol	Grease	OM - Closed system	0.2 kg	No	-
95-38-5	2-(2-heptadec-8-enyl-2-imidazolin-1-yl)ethanol	Grease	OM - Closed system	25 kg	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
25852-47-5	2-(2-methylprop-2-enoyloxy)ethyl 2-methylprop-2-enoate	Other	MM - Closed system	0.1 L	-	-
28064-14-4	2-(chloromethyl)oxirane; Formaldehyde; Phenol	Coating	MM - Closed system	No information	-	-
61791-44-4	2,2'-(C16-18 (evennumbered, C18 unsaturated) alkyl imino) diethanol	Transformer oil	OM - Closed system	20 L	No	-
25307-17-9	2,2'-(octadec-9-enylimino)bisethanol	Hydraulic oil	OM - Closed system	10 L	No	-
26761-45-5	2,3-epoxypropyl neodecanoate	Lubricant	OM - Closed system	26.5 kg	No	-
126-86-3	2,4,7,9-tetramethyldec-5-yne-4,7-diol	Coating	MM - Closed system	3.5 L	No	-
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Grease	OM - Closed system	18 kg	-	-
59656-20-1	2,5-bis(tert-dodecyldithio)-1,3,4-thiadiazole	Grease	OM - Closed system	5 kg	-	-
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	40 L	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	10000 - 98000 kg	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	100000-112000 kg	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Insulating gas/fluid	OM - Closed system	55710 L	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Hydraulic oil	OM - Closed system	52 L	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Hydraulic oil	OM - Closed system	240 L	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
128-37-0	2,6-di-tert-butyl-p-cresol	Insulating gas/fluid	OM - Closed system	226600 kg	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	23000-182000 kg	No	-
128-37-0	2,6-di-tert-butyl-p-cresol	Lubricant	OM - Closed system	26.5 kg	No	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	0.5 L	No	-
204-884-0	2,6-di-tert-butylphenol	Other	OM - Closed system	1.8 L	No	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	730 L	No	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	No information	No	-
128-39-2	2,6-di-tert-butylphenol	Transformer oil	OM - Closed system	20 L	No	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	20 L	No	-
141-43-5	2-aminoethanol	Other	MM - Closed system	2.4 L	No	-
103-97-8	2-ethylhexyl acrylate	Coating	MM - Closed system	1.6 L	-	-
140-31-8	2-piperazin-1-ylethylamine	Coating	MM - Closed system	No information	PT	-
5397-31-9	3-(2-ethylhexyloxy)propylamine	Other	OM - Closed system	3.57 kg/year	-	-
268567-32-4	3-(diisobutoxy-thiophosphorylsulfanyl)-2-methyl-propionic acid	Hydraulic oil	OM - Closed system	20 L	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
26741-53-7	3,9-bis(2,4-di-tert-butylphenoxy)-2,4,8,10-tetraoxa-3,9-diphosphaspiro[5.5]undecane	Grease	OM - Closed system	5 kg	No	-
10254-57-6	4,4'-methylene bis(dibutyldithiocarbamate)	Gear Oil/lubricant	OM - Closed system	1474-1897 L	No	-
10254-57-6	4,4'-methylene bis(dibutyldithiocarbamate)	Grease	OM - Closed system	140-9380 L	No	-
55965-84-9	5-chloro-2-methyl-2H-isothiazol-3-one	Coolant	OM - Closed system	No information	No	-
55965-84-9	5-chloro-2-methyl-2H-isothiazol-3-one	Other	MM - Closed system	as required	No	-
85535-85-9	Alkanes, C14-17, chloro	Coating	MM - Closed system	24 kg	No	-
68955-53-3	Amines, C10-C14-tert-alkyl	Gear Oil	OM - Closed system	7.7 L	No	-
80939-62-4	Amines, C11-14-branched alkyl, monohexyl and dihexyl phosphates	Gear Oil	OM - Closed system	2 kg	No	-
68187-67-7	Amines, C12-14-alkyl, isooctyl phosphates	Grease	OM - Closed system	0.2 kg	-	-
68187-67-7	Amines, C12-14-alkyl, isooctyl phosphates	Grease	OM - Closed system	25 kg	-	-
91745-46-9	Amines, C12-14-alkyl, reaction products with hexanol, phosphorus oxide (P2O5), phosphorus sulfide (P2S5) and propylene oxide	Gear Oil	OM - Closed system	20 L	-	-
91745-46-9	Amines, C12-14-alkyl, reaction products with hexanol, phosphorus	Gear Oil	OM - Closed system	2 kg	-	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
	oxide (P2O5), phosphorus sulfide (P2S5) and propylene oxide					
139734-65-9	Amines, N-C10–C16-alkyltrimethylenedi-, reaction products with chloroacetic acid	Other	MM - Closed system	1260 pcs	No	-
147880-09-9	Amines, Polyethylenepoly	Lubricant	OM - Closed system	1350 L	-	-
68442-69-3	Benzol, C10-14- Alkylderivate	Gear Oil	OM - Closed system	1474-1897 L	-	-
722503-68-6	Benzenesulfonic acid, methyl-, mono-C20-24-branched alkyl derivs., calcium salts	Lubricant	OM - Closed system	1350 L	-	-
80-05-7	Bisphenol A	Coating	MM - Closed system	No information	No	OSPAR list of possible concern, endocrine disrupting substances ECHA, SVHC
80-05-7	Bisphenol A	Other	MM - Closed system	0.1 L	No	OSPAR list of possible concern, endocrine disrupting substances ECHA, SVHC
125643-61-0	C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	Other	OM - Closed system	10 L	PT	-
125643-61-0	C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	Lubricant	OM - Closed system	No information	PT	-
61791-10-4	Cocoalkylmethyl[polyoxyethylene] ammonium chloride	Coating	MM - Closed system	98 L	-	-
98-82-8	Cumene	Other	MM - Closed system	0.1 L	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
110-82-7	Cyclohexane	Grease	MM - Closed system	2 L	No	-
26183-52-8	Decanol, ethoxylated	Other	OM - Closed system	No information	-	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	No information	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Grease	OM - Closed system	5 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Gear Oil	OM - Closed system	1.1 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	No information	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Grease	OM - Closed system	140 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Gear Oil	OM - Closed system	528 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	1350 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Hydraulic oil	OM - Closed system	1250 L	No	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	675 L	No	-
26444-49-5	Diphenyl tolyl phosphate	Coating	MM - Closed system	10 L	-	-
EC: 921-024-6	Hydrocarbons, C6-C7, n-alkanes, isoalkanes, cyclics, <5% n-hexane	Other	MM - Closed system	5.4 L	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
7722-84-1	Hydrogen peroxide	Other	MM - Closed system	30 L	-	-
7722-84-1	Hydrogen peroxide	Other	MM - Closed system	32 L	-	-
7439-92-1	Lead	Batteries	OM - Closed system	184 kg	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	15768 kg	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	2 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	224 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	52 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	260 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	2 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
7439-92-1	Lead	Batteries	OM - Closed system	No information	-	SIN-list, SVHC, OSPAR chemical of priority action

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
7439-92-1	Lead	Batteries	OM - Closed system	8 batteries	-	SIN-list, SVHC, OSPAR chemical of priority action
1309-60-0	Lead dioxide	Batteries	OM - Closed system	224 batteries	-	-
1309-60-0	Lead dioxide	Batteries	OM - Closed system	260 batteries	-	-
1309-60-0	Lead dioxide	Batteries	OM - Closed system	8 batteries	-	-
94270-86-7	N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine	Gear Oil	OM - Closed system	2 kg	-	-
90-30-2	N-1-naphthylaniline	Grease	OM - Closed system	0.35 kg	No	-
90-30-2	N-1-naphthylaniline	Grease	OM - Closed system	0.06 kg	No	-
91-20-3	Naphthalene	Other	MM - Closed system	4.4 L	No	SIN-list, OGewV
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Closed system	18 kg	No	-
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Closed system	18 kg	No	-
12001-85-3	Naphthenic acids, zinc salts	Gear Oil	OM - Closed system	2 kg	No	-
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Closed system	1 kg	No	-
12001-85-3	Naphthenic acids, zinc salts	Lubricant	OM - Closed system	0.2 kg	No	-
12001-85-3	Naphthenic acids, zinc salts	Lubricant	OM - Closed system	0.3 kg	No	-
110-54-3	N-hexane	Grease	MM - Closed system	2 L	No	SIN-list
7440-02-0	Nickel	Other	MM - Closed system	4.4 L	-	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
25154-52-3	Nonylphenol	Coating	MM - Closed system	No information	-	SIN-list, OSPAR list of possible concern, SVHC due to being endocrine disrupting
9016-45-9	Nonylphenol, ethoxylated	Hydraulic oil	OM - Closed system	20 L	PBT	OSPAR list of possible concern, SVHC due to being endocrine disrupting
8012-95-1	Paraffin oils	Gear Oil	OM - Closed system	1.1 L	-	-
109-66-0	Pentane	Grease	MM - Closed system	2 L	No	-
79-21-0	Peracetic acid	Other	MM - Closed system	30 L	No	-
79-21-0	Peracetic acid	Other	MM - Closed system	32 L	No	-
756-13-8	Perfluoro-2-methyl-3-pentanone	Fire protection	OM - Closed system	3120 L	No	-
756-13-8	Perfluoro-2-methyl-3-pentanone	Fire protection	OM - Closed system	2320 kg	No	-
121158-58-5	Phenol, dodecyl-, branched	Gear oil	OM - Closed system	40 L	PT	SIN-list, endocrine disrupting substances ECHA
121158-58-5	Phenol, dodecyl-, branched	Lubricant	OM - Closed system	No information	PT	SIN-list, endocrine disrupting substances ECHA
121158-58-5	Phenol, dodecyl-, branched	Lubricant	OM - Closed system	675 L	PT	SIN-list, endocrine disrupting substances ECHA

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
68512-30-1	Phenol, methylstyrenated	Coating	MM - Closed system	1.3 L	-	-
68512-30-1	Phenol, methylstyrenated	Coating	MM - Closed system	3.8 L	-	-
84605-29-8	Phosphorodithioic acid, mixed O,O-bis(1,3-dimethylbutyl and iso-Pr) esters, zinc salts	Transformer oil	OM - Closed system	20 L	No	-
68457-79-4	Phosphorodithioic acid, mixed O,O-bis(iso-Bu and pentyl) esters, zinc salts	Grease	OM - Closed system	50 L	-	-
68457-79-4	Phosphorodithioic acid, mixed O,O-bis(iso-Bu and pentyl) esters, zinc salts	Lubricant	OM - Closed system	0.3 kg	No	-
68457-79-4	Phosphorodithioic acid, mixed O,O-bis(iso-Bu and pentyl) esters, zinc salts	Grease	OM - Closed system	19.6 kg	No	-
68784-31-6	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and 1,3-dimethylbutyl) esters, zinc salts	Lubricant	OM - Closed system	No information	No	-
68784-31-6	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and 1,3-dimethylbutyl) esters, zinc salts	Transformer oil	OM - Closed system	20 L	No	-
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Gear Oil	OM - Closed system	40 L	-	-
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Lubricant	OM - Closed system	1444 L	-	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Transformer oil	OM - Closed system	20 L	-	-
3811-04-9	Potassium chlorate	Other	OM - Closed system	10 pcs	-	-
3811-73-2	Pyridine-2-thiol 1-oxide, sodium salt	Other	MM - Closed system	10 L	-	-
412-780-3	Reaction product of ammonium molybdate and C12-C24-diethoxylated alkylamine (1:5-1:3)	Grease	OM - Closed system	7 L	-	-
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Gear Oil	OM - Closed system	160 - 821 L	-	-
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Gear Oil	OM - Closed system	160 L	-	-
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Lubricant	OM - Closed system	0.3 kg	-	-
68038-41-5	Resimal F-235	Other	MM - Closed system	19 L	-	-
255881-94-8	S-(tricyclo(5.2.1.0'2,6)deca-3-en-8(or 9)-yl O-(isopropyl or isobutyl or 2-ethylhexyl) O-(isopropyl or isobutyl or 2-ethylhexyl) phosphorodithioate	Hydraulic oil	OM - Closed system	No information	No	-
64665-57-2	Sodium 4(or 5)-methyl-1H-benzotriazolide	Other	MM - Closed system	10 L	No	-
142-87-0	Sodium decyl sulphate	Fire protection	OM - Closed system	45 L	No	-
7681-52-9	Sodium hypychlorite	Other	MM - Closed system	60 L	-	-
8052-41-3	Stoddard solvent	Other	MM - Closed system	0.25 L	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
112-24-3	Trientine	Coating	MM - Closed system	1.3 L	-	-
1330-78-5	Tris(methylphenyl) phosphate	Hydraulic oil	OM - Closed system	240 L	No	-
1330-78-5	Tris(methylphenyl) phosphate	Gear oil	OM - Closed system	7.7 L	No	-
7779-90-0	Trizinc bis(orthophosphate)	Other	MM - Closed system	4.8 L	-	-
7779-90-0	Trizinc bis(orthophosphate)	Coating	MM - Closed system	10 L	-	-
8042-47-5	White mineral oil (petroleum)	Transformer oil	OM - Closed system	140810 kg	PB	-
8042-47-5	White mineral oil (petroleum)	Lubricant	OM - Closed system	1 L	PB	-
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	1100 L	PB	-
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	3000 L	PB	-
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	60 L	PB	-
8042-47-5	White mineral oil (petroleum)	Other	MM - Closed system	2.4 L	PB	-
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	20 L	PB	-
93819-94-4	Zinc bis[O-(6-methylheptyl)] bis[O-(sec-butyl)] bis(dithiophosphate)	Hydraulic oil	OM - Closed system	52 L	No	-
93819-94-4	Zinc bis[O-(6-methylheptyl)] bis[O-(sec-butyl)] bis(dithiophosphate)	Other	MM - Closed system	5 L	No	-
93819-94-4	Zinc bis[O-(6-methylheptyl)] bis[O-(sec-butyl)] bis(dithiophosphate)	Lubricant	OM - Closed system	No information	No	-

CAS nr[1]	Substance	Material category	Open/closed system	Volume/ mass of operational material	PBT criteria[2]	Occurrence on substance classification list
4259-15-8	Zinc bis[O,O-bis(2-ethylhexyl)] bis(dithiophosphate)	Grease	OM - Closed system	19.6 L	No	-
1314-13-2	Zinc oxide	Other	MM - Closed system	1 L	-	-
1314-13-2	Zinc oxide	Other	MM - Closed system	2 L	-	-
1314-13-2	Zinc oxide	Other	MM - Closed system	4.4 L	-	-
1314-13-2	Zinc oxide	Lubricant	OM - Closed system	5 kg	-	-
1314-13-2	Zinc oxide	Coating	MM - Closed system	16 L	-	-
1314-13-2	Zinc oxide	Coating	MM - Closed system	10 L	-	-
1314-13-2	Zinc oxide	Other	MM - Closed system	4.5 L	-	-
80-15-9	α,α-dimethylbenzyl hydroperoxide	Other	MM - Closed system	0.1 L	No	-
80-15-9	α,α-dimethylbenzyl hydroperoxide	Other	MM - Closed system	0.1 L	No	-
80-15-9	α,α-dimethylbenzyl hydroperoxide	Other	MM - Closed system	0.15 L	No	-
80-15-9	α,α-dimethylbenzyl hydroperoxide	Other	MM - Closed system	0.08 L	No	-

[1] CAS numbers represent a unique numerical identifier assigned by the Chemical Abstracts Service (CAS)

[2] PBT criteria according to REACH Regulation; “-“ assigns the absence on PBT information; “No” depicts the no PBT criteria according to the REACH regulation

5.2.2 Resulting list of non-hazardous substances according to the criteria applied

In total 321 substances were identified in this project. From these 321 individual substances, 107 were deemed hazardous according to the criteria applied in this study, resulting in a total of 214 substances which are listed as non-hazardous substances. The list of non-hazardous substances can be found in in Appendix A.

5.3 Selection of hazardous substances for additional analysis on substance amounts and measured concentrations in the marine environment

In order to assess the risk to the marine environment from the identified hazardous substances, their potential masses/volume present on the offshore structures has been evaluated and the occurrence of these substances in the marine environment of the North- and Baltic Sea has been checked. Therefore, 41 substances of special interest have been selected in cooperation with UBA, based on the lists of hazardous substance presented in Table 7 , Table 8 and Table 9, in order to check if these substances have been measured in water, sediment or biota in the North Sea or Baltic Sea. The substances of special interest were investigated regarding their specific amounts in the associated operational materials (see Section 5.3.1). Further, their occurrence in the marine environment is investigated (see Section 5.3.2). Of the 41 substances, 37 have been selected based on 4 criteria:

- The substance meets a P/B/T criterion
- The substance is present on the list for hazardous substances in open systems
- The substance is present on the list for hazardous substances for closed systems with a higher risk for accidents
- The substance is used in a high amount. The mass or volume of the associated operational material exceeded 200 L or 200 kg

Additional 3 substances have been added after consultation of UBA experts: The substances with following CAS numbers 1330-43-4 (disodium tetraborate, anhydrous) and CAS: 12179-04-3 (disodium tetraborate, pentahydrate) are present as a candidate for SVHC list. Further, the substance with CAS: 94270-86-7 (N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine) was shortlisted due to ECHA CLP notifications on being toxic to aquatic life with long lasting effects. Furthermore, fluorosurfactants are included to the substances of special interest. The final selection and the association to the selection criteria is presented in Table 10.

Table 10: List of selected hazardous substances of special interest and selection criteria

CAS no.[1]	Substance	PBT[2] criteria	Open system[3]	High risk[4]	High amount[5]	Others
10254-57-6	4,4'-methylene bis(dibutyldithiocarbamate)				X	
110-54-3	N-hexane	X				
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts				X	
12001-85-3	Naphthenic acids, zinc salts				X	

CAS no.[1]	Substance	PBT[2] criteria	Open system[3]	High risk[4]	High amount[5]	Others
121158-58-5	Phenol, dodecyl-, branched	X		X	X	
125643-61-0	C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	X				
128-37-0	2,6-di-tert-butyl-p-cresol				X	
128-39-2	2,6-di-tert-butylphenol	X			X	
1317-38-0	Copper oxide		X			
1330-78-5	Tris(methylphenyl) phosphate				X	
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole				X	
140-31-8	2-piperazin-1-ylethylamine	X				
142-87-0	Sodium decyl sulphate			X		
147880-09-9	Amines, Polyethylenepoly				X	
151006-58-5	1-Dodecene dimer with 1-Decene, hydrogenated				X	
25154-52-3	Nonylphenol	X				
2634-33-5	1,2-benzisothiazol-3(2H)-one			X	X	
2682-20-4	2-methyl-2H-isothiazol-3-one			X	X	
67124-09-8	1-(tert-dodecylthio)propan-2-ol	X				
68442-69-3	Benzene, C20-24 (even numbered) sec-alkyl derivs.				X	
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	X			X	
722503-68-6	Benzenesulfonic acid, methyl-, mono-C20-24-branched alkyl derivs., calcium salts				X	
7439-92-1	Lead	X			X	
7439-97-6	Mercury	X	X			
7440-02-0	Nickel	X				
7440-43-9	Cadmium	X	X			
7440-50-8	Copper		X			
7440-66-6	Zinc		X			
7440-74-6	Indium		X			

CAS no.[1]	Substance	PBT[2] criteria	Open system[3]	High risk[4]	High amount[5]	Others
756-13-8	Perfluoro-2-methyl-3-pentanone				X	
7681-52-9	Sodium hypochlorite		X			
80-05-7	Bisphenol A		X			
8028-48-6	Orange, sweet, ext.		X			
8042-47-5	White mineral oil (petroleum)	X			X	
8052-41-3	Stoddard solvent		X			
9016-45-9	Nonylphenol, ethoxylated	X				
91-20-3	naphthalene	X		X	X	
94270-86-7	N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine					X
	Fluorosurfactants/component					X
1330-43-4	Disodium tetraborate, anhydrous					X
12179-04-3	Disodium tetraborate, pentahydrate					X

[1] CAS numbers represent a unique numerical identifier assigned by the Chemical Abstracts Service (CAS)

[2] PBT criteria according to REACH Regulation

[3] Selection criteria, if substance is present on list of hazardous substances in open systems

[4] Selection criteria, if substance is present on list of hazardous substances in closed systems with a higher risk of accidents

[5] Selection criteria, if associated operational material has more than 200 kg or 200 l of mass/volume

5.3.1 Analysis of specific amounts of substances

The selected substances in Table 10 are investigated to determine their mass/volume percentage within the operational material. Therefore, the available safety data sheets of the operational materials were analysed to determine the volume/mass percentage of the compound in the mixture. Be aware that the amounts given for the operational material or substance are based on total amounts, which are present on an Offshore structure according to the investigated waste- and operational materials concepts and emission studies. The amounts give no insights into the actual consumption per year.

In the cases that a range of the mass/volume percentage is given in Table 11, the specific volumes are given as a lower and upper volume. Individual substances are present in more than one operational material. In this case the voluminal/mass of each individual occurrence in an operational material is listed. In the case that the amount of an operational material is given in a range, the upper and lower limit of the substance amount is based on the maximum volume/mass of the operational material as conservative assumptions. The upper and lower limit of the substance volume/mass is rounded to the first decimal place. In some cases, the CAS numbers specified in the wind farm waste- and operational materials concepts and emission studies are not occurring in the associated MSDS provided or gathered from online sources. This can be related to varying compositions of materials over time. Further, some MSDS do not mention a certain volume/mass percentage due to confidentiality. In both cases a comment is placed in the column of "Volume/mass percentage". The specific volumes/mass of the selected substances is presented in Table 11.

In the following, the substances presented in Table 11 with higher amounts are discussed in more detail.

Lubricants

5 of the substances with higher amounts can be associated to lubricants such as 4,4'-methylene bis (CAS: 10254-57-6) in a gear oil (max. 73.7 L) and a grease (max. 938 L), 1-Dodecene dimer with 1-Decene (CAS: 151006-58-5) in a grease (max. 2814 l), Dialkyl(C1-C14)dithiophosphoric acid (CAS: 68649-42-3) in a lubricant (max. 40,5 L) and amines, polyethylenepoly (CAS: 147880-09-9) in a lubricant (max. 67.5 L). While the first 4 materials are associated to a single OWT application, the latter one is present on a single OSS.

Insulating/Transformer oils

On OSS platforms also high amounts of insulating or transformer oils are present, which include high amounts of substance 2,6-di-tert-butyl-p-cresol (CAS: 128-37-0) in insulating gas/fluid 1 (max. 235.2 kg), insulating gas/fluid 2 (max. 728 kg), insulating gas/fluid 3 (max. 906.4 kg) and transformer oil (448 kg).

Fire protection

Further, fire protection materials lead to high amounts of identified hazardous substances. The substance perfluoro-2-methyl-3-pentanone (CAS: 756-13-8) is applied with max. 3104.4 L in fire protection material 1 and max. 2308 kg in fire protection material 2. Both operational materials have been found on OSS structures. Fluorosurfactant substances are present in the form of AFFF foams at the helicopter decks of OSS structures. The volume percentage of fluorosurfactants in the AFFF foams varies between 1 and 3%. The maximum volume associated to fluorosurfactants are 23.85 L.

Hydraulic oil

White mineral oil (petroleum) (CAS: 8042-47-5) is listed as a potential hazardous substance, which is present in hydraulic oils. However, although it is listed in the MSDS, it can be one out of a number of mineral oils. Thus, it is unsure if indeed a specific substance is applied in the material. However, since mineral oils are registered as a high percentage component of hydraulic oils, the amounts of the substance are expected to be high if the amount of the operational material is high. The only specific information on white mineral oil in a hydraulic oil is given for a hydraulic oil with max. 2700 L.

Corrosion protection – Galvanic anodes

Table 11 specifies the amounts of selected hazardous substances, which are present in operational materials such as oils or fire protection. However, also metals of galvanic cathodic protection are listed as hazardous substances of special interest in Table 10. The amounts of those metals can be estimated by the amounts presented in Table 4, Thereby, Table 4,

Table 5

Table 5 and Table 6 give an idea about emitted masses per year over a certain lifetime of a structure. Since, the monopile is the most frequent foundation structure in the windfarms commissioned today, the calculated amounts per metal for an OWT are based on a mean value for monopile foundations. The amounts are estimated for a model windfarm which is including 80 OWT and 1 OSS. This gives the following masses per year for a windfarm: zinc 783 kg/a, cadmium 0.82 kg/year and indium 5.13 kg/year. The emission of mercury is registered for one OWT structure only (0.1 kg/(a*turbine)). Thus, this value is expected to be less representable. Also, the emissions for an OCP platform are given for one structure only, thus also those values need to be handled with caution: zinc 139 kg/a, cadmium 0.07 kg/a and indium 5.13 kg/a.

Table 11: List of selected hazardous substances of special interest and the determined substance mass/volume

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
10254-57-6	4,4'-methylene bis(dibutyldithiocarbamate)	Gear Oil	OM - Closed system	1474 L	L	1 - < 5%	14.74	73.7	L
10254-57-6	4,4'-methylene bis(dibutyldithiocarbamate)	Grease	OM - Closed system	140-18760	L	1 - < 5%	187.6	938	L
110-54-3	N-hexane	Grease	MM - Closed system	2	L	≥0.25-<2.5%	0.005	0.05	L
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Lubricant	OM - Closed system	1444	L	1 - < 2.5%	14.4	36.1	L
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Transformer oil	OM - Closed system	20	L	< 2.4%	0.0	0.5	L
113706-15-3	Phosphorodithioic acid, mixed O,O-bis(sec-Bu and isooctyl) esters, zinc salts	Gear oil	OM - Closed system	40	L	1 - 2.5%	0.4	1	L
12001-85-3	Naphthenic acids, zinc salts	Gear Oil	OM - Accidents	67	L	not in MSDS	-	-	-
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Accidents	67	L	1 - 2.5%	0.7	1.7	L
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Accidents	67	L	not in MSDS	-	-	-
12001-85-3	Naphthenic acids, zinc salts	Gear Oil	OM - Closed system	2	kg	≥ 1 - < 2.5	0.02	0.05	kg
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Closed system	2.12	kg	< 2.5%	-	0.1	kg
12001-85-3	Naphthenic acids, zinc salts	Lubricant	OM - Closed system	0.3	kg	1 - 2.49%	0.003	0.0075	kg
12001-85-3	Naphthenic acids, zinc salts	Lubricant	OM - Closed system	0.2-18	kg	0.25 - 0.9%	0.1	16.2	kg
12001-85-3	Naphthenic acids, zinc salts	Grease	OM - Closed system	18	kg	0.1 - 0.9%	0.02	0.2	kg
121158-58-5	Phenol, dodecyl-, branched	Lubricant	OM - Closed system	#N/A	-	No material specified	-	-	-

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
121158-58-5	Phenol, dodecyl-, branched	Lubricant	OM - Closed system	675	L	< 0.25%	-	1.7	L
121158-58-5	Phenol, dodecyl-, branched	Gear Oil	OM - Closed system	40	L	0.1 - < 0.25%	0.04	0.1	L
12179-04-3	Disodium tetraborate, anhydrous	Antifreeze	OM - Closed system	630	L	0.3-1%	1.9	6.3	L
12179-04-3	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	450	L	≥ 0,3% - ≤ 1%	1.4	4.5	L
125643-61-0	C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	Lubricant	OM - Closed system	0	-	< 5%	-	-	-
125643-61-0	C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	other	OM - Closed system	10	L	No material specified	-	-	-
128-37-0	2,6-di-tert-butyl-p-cresol	Hydraulic oil	OM - Closed system	52	L	0.1 - < 1%	0.1	0.5	L
128-37-0	2,6-di-tert-butyl-p-cresol	Hydraulic oil	OM - Closed system	240	L	0.1 - < 1%	0.2	2.	L
128-37-0	2,6-di-tert-butyl-p-cresol	Insulating gas/fluid	OM - Closed system	98000	kg	0.1 - 0.24%	98	235.2	kg
128-37-0	2,6-di-tert-butyl-p-cresol	Insulating gas/fluid	OM - Closed system	55710	L	not in MSDS	-	-	-
128-37-0	2,6-di-tert-butyl-p-cresol	Insulating gas/fluid	OM - Closed system	226600	kg	<0.4%	-	906.4	kg
128-37-0	2,6-di-tert-butyl-p-cresol	Lubricant	OM - Closed system	26.5	kg	0.1-1.0 %	0.03	0.3	kg
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	23000-182000	kg	<0.4%	-	728	kg
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	10400	L	0.1 - 0.24%	10.4	25.0	L
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	80	L	0.1 - 0.24%	0.1	0.2	L
128-37-0	2,6-di-tert-butyl-p-cresol	Transformer oil	OM - Closed system	100000-112000	kg	< 0.4%	-	448	kg

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	730	L	<0.25%	-	1.8	L
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	-	-	0.1 - < 1%	-	-	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	0.5	L	not in MSDS	-	-	-
128-39-2	2,6-di-tert-butylphenol	Hydraulic oil	OM - Closed system	20	L	0.1 - 0.249%	0.02	0.05	L
128-39-2	2,6-di-tert-butylphenol	Transformer oil	OM - Closed system	20	L	0.1 - 0.99%	0.02	0.2	L
1317-38-0	Copper oxide	Antifouling (ICAF)	Open System	-	-	not in MSDS	-	-	-
1330-43-4	Disodium tetraborate, anhydrous	Grease	OM - Closed system	30	L	not in MSDS	-	-	-
1330-43-4	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	580	L	≤ 5%	-	29	l
1330-43-4	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	-	-	≥ 0,3% - ≤1%	-	-	-
1330-78-5	Tris(methylphenyl) phosphate	Hydraulic oil	OM - Closed system	240	L	0.1 - < 1%	0.2	2.4	L
1330-78-5	Tris(methylphenyl) phosphate	Gear oil	OM - Closed system	7.7	L	0.1 - < 0.25%	0.01	0.02	L
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Gear Oil	OM - Closed system	160-821	L	≤0.3%	-	2.4	L
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Lubricant	OM - Closed system	0.3	kg	< 0.09%	-	0.0003	kg
13539-13-4	2,5-bis(octyldithio)-1,3,4-thiadiazole	Grease	OM - Closed system	18	kg	< 0.09%	-	0.02	kg
140-31-8	2-piperazin-1-ylethylamine	Coating	MM - Closed system	-	-	10 - 25%	-	-	-
142-87-0	Sodium decyl sulphate	Fire protection	OM - Accidents	200-400	L	< 5%	-	20	L
142-87-0	Sodium decyl sulphate	Fire protection	OM - Accidents	400	L	< 5%	-	20	L
142-87-0	Sodium decyl sulphate	Fire protection	OM - Accidents	50	L	5-10%	2.5	5	L

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
142-87-0	Sodium decyl sulphate	Fire protection	OM - Closed system	45	L	0.1 - 1%	0.05	0.5	L
147880-09-9	AMINES, POLYETHYLENEPOLY	Lubricant	OM - Closed system	1350	L	1 - <5%	13.5	67.5	L
151006-58-5	1-Dodecene dimer with 1-Decene, hydrogenated	Grease	OM - Closed system	120-8040	L	25 – 35%	2010	2814	L
151006-58-5	1-Dodecene dimer with 1-Decene, hydrogenated	Grease	OM - Closed system	174-240	L	not in MSDS	-	-	-
25154-52-3	Nonylphenol	Coating	MM - Closed system	-	-	not in MSDS	-	-	-
2634-33-5	1,2-benzisothiazol-3(2H)-one	Fire protection	OM - Accidents	240	L	< 0.1%	-	0.2	L
2682-20-4	2-methyl-2H-isothiazol-3-one	Fire protection	OM - Accidents	240	L	< 0.1%	-	0.2	
67124-09-8	1-(tert-dodecylthio)propan-2-ol	Hydraulic oil	OM - Closed system	10	L	≤ 0.5%	-	0.0	L
68442-69-3	Benzene, C20-24 (even numbered) sec-alkyl derivs.	Gear Oil	OM - Closed system	1474-1897	L	0.1-< 0.25%	1.9	4.7	L
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Gear Oil	OM - Closed system	528	L	1 - 2.4%	5.3	12.7	L
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Gear Oil	OM - Closed system	1.1	L	no MSDS	-	-	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Grease	OM - Closed system	140	L	1 - 2.5%	1.4	3.5	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Grease	OM - Closed system	5	L	1 - 5%	0.1	0.3	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Hydraulic oil	OM - Closed system	1250	L	not in MSDS	-	-	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	#N/A	-	not in MSDS	-	-	-

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	675	L	< 2.5 %	-	16.9	L
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	-	-	1 - 1.99%	-	-	-
68649-42-3	Dialkyl(C1-C14)dithiophosphoric acid, zinc salt	Lubricant	OM - Closed system	1350	L	1 - <3%	13.5	40.5	-
722503-68-6	Benzenesulfonic acid, methyl-, mono-C20-24-branched alkyl derivs., calcium salts	Lubricant	OM - Closed system	1350	L	0.1- <1%	1.4	13.5	L
7439-92-1	Lead	Batteries	OM - Closed system	260	Batteries	60 - 70 %	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	2	Batteries	64% per weight	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	2	Batteries	63-81% per weight	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	-	-	no MSDS available	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	224	Batteries	no MSDS available	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	8	Batteries	45 - 55%	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	52	Batteries	not in MSDS	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	15768	kg	not in MSDS	-	-	-
7439-92-1	Lead	Batteries	OM - Closed system	6 á 30.6 kg = 183.6	kg	not in MSDS	-	-	-
7439-97-6	Mercury	Sacrificial anodes	Open System	-	-	-	-		
7440-02-0	Nickel	Other	MM - Closed system	4.4	L	0.1 - <1%	0.004	0.04	L

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
7440-43-9	Cadmium	Sacrificial anodes	Open System	-	-	-	-		
7440-50-8	Copper	Other	MM - Closed system	0.11	kg	7-13%	0.008	0.014	kg
7440-66-6	Copper	Lubricant	OM - Closed system	5	kg	not in MSDS	-	-	-
7440-66-6	Zinc	Coating	MM - Closed system	16	L	≥50 - 75%	8	12	L
7440-66-6	Zinc	Coating	MM - Closed system	0.8	L	25 - 50%	0.2	0.4	L
7440-66-6	Zinc	Coating	MM - Closed system	0.5	L	50 - 75%	0.3	0.4	L
7440-66-6	Zinc	Other	MM - Closed system	4.5	L	40 - 60%	1.8	2.7	L
7440-66-6	Zinc	Other	MM-Closed system	0.04	L	25 - <50	0.01	0.02	L
7440-66-6	Zinc	Oother	OM - Closed system	as required	-	25 - <50	-	-	-
7440-66-6	Zinc	Sacrificial anodes	Open System	-	-	-	-	-	-
7440-74-6	Indium	Sacrificial anodes	Open System	-	-	-	-	-	-
756-13-8	Perfluoro-2-methyl-3-pentanone	Fire protection	OM - Closed system	3120	L	>99.5%	-	3104.4	L
756-13-8	Perfluoro-2-methyl-3-pentanone	Fire protection	OM - Closed system	2319.6	kg	>99.5%	-	2308.0	kg
7681-52-9	Sodium hypochlorite	Other	MM - Closed system	60	L	10-30%	6	18	L
7681-52-9	Sodium hypochlorite	Antifouling	Open System	-			-	-	-
80-05-7	Bisphenol A	Coating	MM - Closed system	0	-	not in MSDS	-	-	-
80-05-7	Bisphenol A	Other	MM - Closed system	0.1	L	10-30%	0.01	0.03	L

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
80-05-7	Bisphenol A	Leaching from coatings	Open System				-	-	-
8028-48-6	Orange, sweet, ext.	Other	Open system	40	L	10-30%	4	12	L
8042-47-5	White mineral oil (petroleum)	Other	MM - Closed system	2.4	L	10-30%	0.2	0.7	L
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	60	L	0 -90%	0	54	L
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	3000	L	> 0 < 90%	0	2700	L
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	1100	L	not in MSDS	-	-	-
8042-47-5	White mineral oil (petroleum)	Lubricant	OM - Closed system	1	L	0 -90%	0	0.9	L
8042-47-5	White mineral oil (petroleum)	Hydraulic oil	OM - Closed system	20	L	1-3%	0.2	0.6	L
8042-47-5	White mineral oil (petroleum)	Transformer oil	OM - Closed system	140810	kg	not in MSDS	-	-	-
8052-41-3	Stoddard solvent	Other	MM - Closed system	0.25	L	20-25%	0.1	0.1	L
8052-41-3	Stoddard solvent	Other	Open system	540	L	not in MSDS	-	-	-
9016-45-9	Nonylphenol, ethoxylated	Hydraulic oil	OM - Closed system	20	L	0.1-0.9%	0.02	0.18	L
91-20-3	Naphthalene	Fuel	OM - Accidents	240000	L	no MSDS available	-	-	-
91-20-3	Naphthalene	Other	MM - Closed system	4.4	L	0.1-<1%	0.004	0.044	L
91-20-3	Naphthalene	Fuel	OM - Accidents	6x2000	L	no MSDS available	-	-	-
91-20-3	Naphthalene	Fuel	OM - Accidents	89000	L	no MSDS available	-	-	-

CAS no.[1]	Substance	Operating material type	Open/closed system	Amount Mixture	Unit	Volume/mass percentage	Amount lower limit	Amount upper limit	Unit
94270-86-7	N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine	Gear Oil	OM - Closed system	2	kg	≥ 0.1% - ≤ 0.25%	0.002	0.005	kg
	Fluorosurfactant/component	Fire protection	OM - Accidents	135	L	3%	-	4.1	
	Fluorosurfactant/component	Fire protection	OM - Accidents	795	L	3%	-	23.9	
	Fluorosurfactant/component	Fire protection	OM - Accidents	200	L	1%	-	2	
	Fluorosurfactant/component	Fire protection	OM - Accidents	200	L	1%	-	2	
	Fluorosurfactant/component	Fire protection	OM - Accidents	400	L	3%	-	12	
	Fluorosurfactant/component	Fire protection	OM - Accidents	as required	L	3%	-	-	

[1] CAS numbers represent a unique numerical identifier assigned by the Chemical Abstracts Service

5.3.2 Analysis of measured occurrence of as hazardous identified substances

The selected substances stated in Table 10 are further investigated regarding their occurrence in the marine environment of the North and Baltic Sea. Therefore, the measured occurrences recorded in the MUDAB database are established.

From the 39 substances of special interest provided in Table 10, only 7 substances are registered within measurements in the MUDAB database being monitored in the North Sea and Baltic Sea (Accessed: 03.11.2021). The occurrence of selected hazardous substances is distinguished in occurrence in seawater, in sediment or in biota. For the North Sea and the Baltic Sea, the substances bisphenol A, cadmium, copper, mercury, naphthalene, nickel and lead have been detected in seawater. The analysis of sediment showed occurrences of cadmium, copper, mercury, naphthalene, nickel and lead in the North Sea as well as in the Baltic Sea. Also, the analysis in biota showed the same substances occurring in the North Sea and in the Baltic Sea as cadmium, copper, mercury, naphthalene, nickel and lead. However, the occurrence of these substances in the marine environment can be caused by various sources (incl. atmospheric deposition) and do not need to be linked to the offshore wind industry.

In the research project RESOW, an additional work package is included, with the aim to provide an overview on possible offshore emission sources of the selected hazardous substances (besides the offshore wind industry also from e.g. offshore oil & gas or shipping) and to estimate the associated volumes/masses per source emitted into the environment. Further, the emissions should be compared to emissions from land-based sources onshore. The results of this work package are going to be published in a separate report.

6 Conclusion and recommendations

This study gives insights into the potential sources of emissions of hazardous substances to the marine environment from offshore wind turbines or platforms. The most relevant hazardous substances, which are applied in the offshore wind industry, were analysed in detail.

Identification of possible sources of emissions of hazardous substances during lifetime phases of offshore wind structures

In a first step, possible sources of emissions of hazardous substances were identified. Therefore, the activities performed, and materials used during the installation, operation or decommissioning phases of offshore wind structures have been analysed.

During the installation phase, no clear source of emissions of hazardous substances can be identified. However, possible emissions of hazardous substances into the seawater might be caused due to ship traffic, the processes involved during the foundation installation and cable laying activities. Cable laying activities can lead to reactivation of hazardous substances in the soil if the re-suspended mobilised sediment contains contaminations. However, the risk can be significantly minimised by avoiding contaminated areas or using cable laying technology which minimises seabed disturbance.

In the decommissioning phase, no potential emissions of hazardous materials are expected, besides the impact of remaining offshore infrastructure in the environment. According to the site development plans of the BSH (2020), a complete decommission of offshore structures can be refrained if the decommission results in more negative effects for the environment than the remains of the structures offshore (e.g., artificial reefs at scour protections), but only as long as the decommission is not required for safety or ease of shipping traffic. Nevertheless, the structure needs to be decommissioned as such, that the top side of the fundament is below the sediment surface and below the working extent of fishing equipment. Also, the possibility of re-usage should be part of the discussion. However, the removal of cables is recommended, since in the case of cable deterioration, metal components might become exposed, which might release heavy metals in the environment.

During the operational phase, more sources need to be investigated on potential emissions. Operational materials applied in technical installations on the structure can include hazardous substances. Further, external (outdoor) technical installations can cause emissions into the water. To distinguish the risk of emissions from a source, the applications of operational materials have been categorised into three different categories: application in open systems, application in closed systems with a higher risk for accidents and application in closed systems. For the investigation of potential sources during operation, waste- and operational materials concepts and emission studies from the permitting process have been provided by the BSH. Based on this information detailed lists of the applied operational materials have been compiled. The lists include information on the application location and purpose, the association to an open/closed - high risk/ closed system, the manufacturer, amounts and more material characteristics.

Identification of possibly hazardous substances

The identified potentials sources of emission have been analysed for hazardous compounds. Therefore, specific substances used in applications such as e.g. antifouling agents have been identified. Further, potential hazardous substances, which are compounds of operational materials have been identified via associated MSDS. The identified potential hazardous substances are further analysed regarding their hazardousness for the marine environment. In this study, a total of 321 individual potential hazardous substances have been identified. Hazardous substances are identified based on PBT criteria, H-phrases and occurrence on substance classification lists. In total 107 substances of 321 individual potential hazardous substances have been identified as hazardous. Based on the available data during the execution of this project, only one substance (nonylphenol, CAS: 9016-45-9) was identified as being persistent, bioaccumulative and toxic (PBT). Two substances were identified as being as persistent and bioaccumulative (dialkyl(C1-C14)dithiophosphoric acid, zinc salt, CAS: 68649-42-3; white mineral oil (petroleum), CAS: 8042-47-5) and three substances were identified as being persistent and toxic (2-piperazin-1-ylethylamine, CAS: 140-31-8; C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate, CAS: 125643-61-0; Phenol, dodecyl-, branched, CAS: 121158-58-5). All these substances are applied in operational materials in closed systems and have therefore a low possibility to be emitted into the environment, only due to e.g. an accident or human failure. 84 substances have been identified as being hazardous based on their assigned H-phrases. But of 21 substances insufficient data are available to assign a specific H-phrase. However, according to the overall characteristics determined from available information they were identified as being possibly harmful to the environment. Four substances in total have been identified as possible endocrine disrupting. Thereby, two are listed on the ECHA list of endocrine disrupting chemicals (Bisphenol A, CAS: 80-05-7 and Phenol, dodecyl-, branched, CAS: 121158-58-5) and two are listed on the list of Substances of Very High Concern (SVHC) (Nonylphenol, CAS: 25154-52-3 and Nonylphenol, ethoxylated, CAS: 9016-45-9).

Identification of the possible risk of hazardous substances to the marine environment

Not all hazardous substances have the potential to be a risk to the marine environment. The risk is not only determined by the chemical characteristics of the substance, but also by the amount of the substance used and the location where the substance is used (e.g. in an open or closed system). Substances that are used in a closed system are much less likely to be emitted into the environment. Three different overviews of hazardous substances are made based on where the substances are being used: hazardous substances used in open systems, hazardous substances which may be emitted only during accidents and hazardous substances used in closed systems.

A total of 11 substances were identified as being hazardous due to their hazardous properties and their use in systems with direct contact with the marine environment (open systems). This group of substances is considered to have the highest probability to be emitted to the marine environment. The main sources of these hazardous substances are from corrosion protection (metals like zinc, indium, etc.) and antifouling agents. The hazardous substances assigned to antifouling are copper oxide and sodium hypochlorite. However, from the 12 offshore wind structures investigated in this study just on one offshore wind structure antifouling measures based on copper anodes could be identified according to the emission and waste- and operational materials concepts provided by BSH. The hazardous substances assigned to corrosion protection are metals from galvanic anodes. The anodes consist of various metals, whereby zinc, cadmium, indium and mercury are compounds of concern. Besides those metals, more metals of concern might be included in small amounts. However, since these metals of smaller percentage are not specified by the manufacturer, no amounts can be determined. For zinc, cadmium and indium amounts can be determined. Therefore, a model windfarm of 80 monopile founded OWT and on OSS was assumed. For this model windfarm the following masses were estimated: zinc 783 kg/a, cadmium 0.82 kg/a and indium 5.13 kg/a. The emissions for an OCP platform are known for one structure only, thus those values need to be handled with caution: zinc 139 kg/a, cadmium 0.07 kg/a and indium 5.13 kg/a.

Five substances and the substance group of fluorosurfactants were identified as being hazardous in closed systems with higher chances of accidents (see Table 8). Main sources from this category are firefighting foams (fluorosurfactants) and fuels used on the helicopter deck of the offshore substation. In the case of an emergency, the hazardous substances (fluorosurfactants; 1,2-benzisothiazol-3(2H)-one, CAS: 2634-33-5; 2-methyl-2H-isothiazol-3-one, CAS: 2682-20-4; Sodium decyl sulphate, CAS: 142-87-0) containing firefighting foams might be emitted into the environment. However, AFF foams are banned according to the site development plan (BSH, 2020). Further, substances assigned to this category are substances in fuels (diesel) (Naphtalene, CAS: 91-20-3). These materials are present on the OSS/OCP structures in high volumes. The transport onto the offshore structure is achieved via bunkering procedure, which bears a higher risk for accidents due to e.g. human failure. Furthermore, grease and gear oils used on external (outdoor) applications of offshore wind structures (e.g. cranes) are also sources of hazardous substances assigned to a closed system with higher risk for accidents (Naphthenic acids, zinc salts, CAS: 12001-85-3).

In total 89 hazardous substances have been identified for use in closed systems. However, without an accident or human failure, these substances have a low possibility to be emitted into the seawater. The security measures offshore should minimise the risk of emissions due to accidents. Currently, no specific technical guideline applies in the German exclusive economic zone (EEZ) regarding the application and use of substances which are hazardous to the aquatic environment. The German Ordinance on Facilities Handling Substances that are Hazardous to Water (AwSV) on the application and use of substances which are hazardous to the aquatic environment for the application onshore is only applicable by law for coastal waters (12 nautical miles) and not in the exclusive economic zone (EEZ) where most offshore wind installations are being built. However, the site development plan (BSH, 2020) gives the requirement to minimise emissions as much as possible. So far, the structural security measures for applications involving high amounts of liquid operational materials need to be ensured on an individual basis. A guideline including security measures and best practice for handling of hazardous substances specifically for the application on offshore wind structures could limit the risk of accidents or spillage due to structural measures.

The risk of emissions of materials applied in a closed system with a higher risk for accidents is mostly due to human failure. Bunkering procedures, exchange of high amounts of hydraulic/gear/transformer oils are bearing a risk, if security measures are applied incorrectly or the procedure is not executed according to a certain protocol. This emphasizes the importance of strict routines, safety protocols and experienced personnel for the maintenance procedure on offshore structures. Also, in the case of a change in maintenance executing company, it needs to be ensured, that the execution of maintenance procedures is not suffering in quality. Further, frequent investigations should be conducted to substitute operational materials or technical installations including hazardous substances with less hazardous substances.

To ensure an appropriate handling of a certain operational material, the material characteristics and hazardous components need to be known. For a large number of operational materials, it is difficult to find appropriate information about its components in e.g. MSDS. An improved availability of information provided by the manufacturers is needed to enable a more undeceived handling of materials, allows a broader and easier investigation for substitutes and raise awareness about risks. The research project “Hazardous industrial chemicals in the IED

BREFs" (HAZBREF) founded by the European Regional Development Fund, Interreg Baltic Sea Region is an important step to improve the availability of information by e.g. utilizing existing information from other EU regulatory frameworks, such as REACH and the Water Framework Directive (SYKE, 2017). Thereby, the project aims to increase the knowledge base of the industrial sources and the reduction measures of hazardous chemicals.

The findings of this study in the RESOW project are the basis for further work packages. Therefore, the technical installations assigned to the identified emission sources of potential hazardous substances are going to be further investigated in the work package 3. The aim of that work package 3 is to identify possibilities to reduce or prevent the emissions from by introducing a first step for best available techniques in offshore wind installations. In another work package 4 the emissions from offshore wind energy should be compared to the emissions taking place from other offshore sources such as e.g. shipping.

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A Appendix – List of substances not identified as hazardous according to the criteria applied

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68990-52-3	Fatty acids, vegetable-oil, Me esters	Fuel	OM - Accidents	240000	L	No	-
68476-34-6	Fuels, diesel, no. 2	Fuel	OM - Accidents	240000	L	No	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	5472	kg	-	-
111-90-0	2-(2-ethoxyethoxy)ethanol	Coating	MM - Closed system	3.5	L	No	-
111-40-0	2.2'-iminodi(ethylamine)	Coating	MM - Closed system	-	-	No	-
108-65-6	2-methoxy-1-methylethyl acetate	Coating	MM - Closed system	0.4	L	No	-
*25068-38-6	4.4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2.3-epoxypropane	Coating	MM - Closed system	3.75	L	No	-
*25068-38-6	4.4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2.3-epoxypropane	Coating	MM - Closed system	135	L	No	-
25068-38-6	4.4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2.3-epoxypropane	Coating	MM - Closed system	-	-	No	-
100-51-6	Benzyl alcohol	Coating	MM - Closed system	3.75	L	No	-
100-51-6	Benzyl alcohol	Coating	MM - Closed system	1.25	L	No	-
100-51-6	Benzyl alcohol	Coating	MM - Closed system	-	-	No	-
106-97-8	Butane	Coating	MM - Closed system	0.8	L	No	-
106-97-8	Butane	Coating	MM - Closed system	0.4	L	No	-
108-94-1	Cyclohexanone	Coating	MM - Closed system	1.25	L	No	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	3.75	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
100-41-4	Ethylbenzene	Coating	MM - Closed system	135	L	-	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	1.25	L	-	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	60	L	-	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	6.5	L	-	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	0.8	L	-	-
10213-79-3	Natriummetasilicat Pentahydrat	Coating	MM - Closed system	98	L	-	-
68609-97-2	Oxirane, mono[(C12-14-alkyloxy)methyl] derivs.	Coating	MM - Closed system	-	-	No	-
124-38-9	Carbon dioxide	Other	MM - Closed system	6.7	L	-	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Other	MM - Closed system	6.7	L	No	-
64742-47-8	Distillates (petroleum), hydrotreated light	Other	MM - Closed system	6.7	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Other	MM - Closed system	6.7	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Other	MM - Closed system	6.7	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Other	MM - Closed system	6.7	L	No	-
64742-71-8	Paraffin oils (petroleum), catalytic dewaxed light	Other	MM - Closed system	6.7	L	No	-
107-98-2	1-methoxypropan-2-ol	Coating	MM - Closed system	10	L	No	-
872-50-4	1-methyl-2-pyrrolidone	Coating	MM - Closed system	24	kg	No	SVHC

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
67-64-1	Acetone	Coating	MM - Closed system	1.6	L	No	-
67-64-1	Acetone	Coating	MM - Closed system	4.8	L	No	-
7429-90-5	aluminium	Coating	MM - Closed system	4.8	L	-	-
13701-59-2	Barium diboron tetraoxide	Coating	MM - Closed system	10	L	-	-
71-36-3	Butan-1-ol	Coating	MM - Closed system	4.8	L	No	PLONOR
106-97-8	Butane	Coating	MM - Closed system	4.8	L	No	-
471-34-1	Calcium carbonate	Coating	MM - Closed system	24	kg	-	PLONOR
64742-47-8	Distillates (petroleum). hydrotreated light	Coating	MM - Closed system	10	L	No	-
141-78-6	Ethyl acetate	Coating	MM - Closed system	4.8	L	No	-
100-41-4	Ethylbenzene	Coating	MM - Closed system	10	L	-	-
64742-48-9	Hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics	Coating	MM - Closed system	4.8	L	No	-
75-28-5	Isobutane	Coating	MM - Closed system	4.8	L	No	-
1332-58-7	Kaolin	Coating	MM - Closed system	24	kg	-	PLONOR
123-86-4	N-butyl acetate	Coating	MM - Closed system	1.6	L	No	-
123-86-4	N-butyl acetate	Coating	MM - Closed system	4.8	L	No	-
74-98-6	Propane	Coating	MM - Closed system	4.8	L	No	-
74-98-6	Propane	Coating	MM - Closed system	1.6	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Coating	MM - Closed system	10	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Coating	MM - Closed system	4.8	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
1330-20-7	Xylene	Coating	MM - Closed system	4.8	L	No	-
67-64-1	Acetone	Glue	MM - Closed system	0.32	L	No	-
141-78-6	Ethyl acetate	Glue	MM - Closed system	0.32	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Grease	MM - Closed system	2	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Grease	MM - Closed system	2	L	No	-
74-98-6	Propane	Grease	MM - Closed system	2	L	No	-
106-97-8	Butane	Lubricant	MM - Closed system	2.4	L	No	-
124-38-9	Carbon dioxide	Lubricant	MM - Closed system	2.4	L	-	-
75-28-5	Isobutane	Lubricant	MM - Closed system	2.4	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Lubricant	MM - Closed system	2.4	L	No	-
74-98-6	Propane	Lubricant	MM - Closed system	2.4	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Other	MM - Closed system	10	L	No	-
111-46-6	2.2'-oxydiethanol	Other	MM - Closed system	25	L	No	-
111-76-2	2-butoxyethanol	Other	MM - Closed system	25	L	No	-
101-68-8	4.4'-methylenediphenyl diisocyanate	Other	MM - Closed system	0.3	L	No	-
67-64-1	Acetone	Other	MM - Closed system	4.4	L	No	-
67-64-1	Acetone	Other	MM - Closed system	5.4	L	No	-
7429-90-5	aluminium	Other	MM - Closed system	4.8	L	-	-
1336-21-6	Ammonia, aqueous solution	Other	MM - Closed system	20	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
22984-54-9	Butan-2-one O,O',O''-(methylsilylidyne)trioxime	Other	MM - Closed system	9	kg	No	-
106-97-8	Butane	Other	MM - Closed system	0.8	L	No	-
106-97-8	Butane	Other	MM - Closed system	1.6	L	No	-
106-97-8	Butane	Other	MM - Closed system	4.4	L	No	-
106-97-8	Butane	Other	MM - Closed system	4.8	L	No	-
78-93-3	Butanone	Other	MM - Closed system	25	L	No	-
78-93-3	Butanone	Other	MM - Closed system	2	L	No	-
78-93-3	Butanone	Other	MM - Closed system	8	L	No	-
78-93-3	Butanone	Other	MM - Closed system	1	L	No	-
1305-62-0	Calcium dihydroxide	Other	MM - Closed system	5	L	-	PLONOR
1305-62-0	Calcium dihydroxide	Other	MM - Closed system	4.8	L	-	PLONOR
124-38-9	Carbon dioxide	Other	MM - Closed system	3.6	L	-	-
124-38-9	Carbon dioxide	Other	MM - Closed system	5.4	L	-	-
77-92-9	Citric acid	Other	MM - Closed system	25	L	No	PLONOR
77-92-9	Citric acid	Other	MM - Closed system	20	L	No	PLONOR
115-10-6	Dimethyl ether	Other	MM - Closed system	4.8	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Other	MM - Closed system	5	L	No	-
64742-47-8	Distillates (petroleum), hydrotreated light	Other	MM - Closed system	0.25	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
141-78-6	Ethyl acetate	Other	MM - Closed system	2	L	No	-
141-78-6	Ethyl acetate	Other	MM - Closed system	8	L	No	-
141-78-6	Ethyl acetate	Other	MM - Closed system	1	L	No	-
141-78-6	Ethyl acetate	Other	MM - Closed system	4.4	L	No	-
56-81-5	Glycerol	Other	MM - Closed system	4.8	L	No	PLONOR
7664-39-3	Hydrogen fluoride	Other	MM - Closed system	25	L	-	-
75-28-5	Isobutane	Other	MM - Closed system	0.8	L	No	-
75-28-5	Isobutane	Other	MM - Closed system	1.6	L	No	-
75-28-5	Isobutane	Other	MM - Closed system	4.4	L	No	-
75-28-5	Isobutane	Other	MM - Closed system	4.8	L	No	-
75-28-5	Isobutane	Other	MM - Closed system	5.4	L	No	-
1332-58-7	Kaolin	Other	MM - Closed system	18.9	L	-	PLONOR
1760-24-3	N-(3-(trimethoxysilyl)propyl)ethylenediamine	Other	MM - Closed system	4.4	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Other	MM - Closed system	2	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Other	MM - Closed system	2	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Other	MM - Closed system	1	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Other	MM - Closed system	1	L	No	-
7664-38-2	Orthophosphoric acid	Other	MM - Closed system	25	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68425-34-3	Petrolatum (petroleum), oxidized, calcium salt	Other	MM - Closed system	0.25	L	No	-
74-98-6	Propane	Other	MM - Closed system	0.8	L	No	-
74-98-6	Propane	Other	MM - Closed system	1.6	L	No	-
74-98-6	Propane	Other	MM - Closed system	4.4	L	No	-
74-98-6	Propane	Other	MM - Closed system	4.8	L	No	-
74-98-6	Propane	Other	MM - Closed system	5.4	L	No	-
64742-01-4	Residual oils (petroleum), solvent-refined	Other	MM - Closed system	0.25	L	No	-
8050-09-7	Rosin	Other	MM - Closed system	2	L	No	-
8050-09-7	Rosin	Other	MM - Closed system	1	L	No	-
1310-73-2	Sodium hydroxide	Other	MM - Closed system	15	L	-	-
92062-15-2	Solvent naphtha (petroleum), hydrotreated light naphthenic	Other	MM - Closed system	8	L	-	-
68910-45-2	Sulfonic acids, alkane, chloro, sodium salts	Other	MM - Closed system	15	L	-	-
64-02-8	Tetrasodium ethylenediaminetetraacetate (EDTA)	Other	MM - Closed system	15	L	No	-
1330-20-7	Xylene	Other	MM - Closed system	0.3	L	No	-
1330-20-7	Xylene	Other	MM - Closed system	4.4	L	No	-
90-72-2	2,4,6-tris(dimethylaminomethyl)phenol	Maintenance - Coating	MM - Closed system	1.25	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
25068-38-6	4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane	Maintenance - Coating	MM - Closed system	3.75	L	No	-
25068-38-6	4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane	Maintenance - Coating	MM - Closed system	135	L	No	-
25068-38-6	4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane	Maintenance - Coating	MM - Closed system	16	L	No	-
67-64-1	Acetone	Maintenance - Coating	MM - Closed system	0.8	L	No	-
67-64-1	Acetone	Maintenance - Coating	MM - Closed system	0.4	L	No	-
68439-46-3	Alcohols, C9-11 ethoxylated, < 2.5 EO	Maintenance - Coating	MM - Closed system	98	L	No	-
71-36-3	Butan-1-ol	Maintenance - Coating	MM - Closed system	135	L	No	PLONOR
71-36-3	Butan-1-ol	Maintenance - Coating	MM - Closed system	16	L	No	PLONOR
71-36-3	Butan-1-ol	Maintenance - Coating	MM - Closed system	6.5	L	No	PLONOR
9003-36-5	Formaldehyde, oligomeric reaction products with 1-chloro-2,3-epoxypropane and phenol	Maintenance - Coating	MM - Closed system	16	L	No	-
75-28-5	Isobutane	Maintenance - Coating	MM - Closed system	0.8	L	No	-
75-28-5	Isobutane	Maintenance - Coating	MM - Closed system	0.4	L	No	-
123-86-4	N-butyl acetate	Maintenance - Coating	MM - Closed system	4.37	L	No	-
123-86-4	N-butyl acetate	Maintenance - Coating	MM - Closed system	0.4	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
67-63-0	Propan-2-ol	Maintenance - Coating	MM - Closed system	0.4	L	No	PLONOR
74-98-6	Propane	Maintenance - Coating	MM - Closed system	0.8	L	No	-
74-98-6	Propane	Maintenance - Coating	MM - Closed system	0.4	L	No	-
64742-94-5	Solvent naphtha (petroleum), heavy arom.	Maintenance - Coating	MM - Closed system	0.4	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Coating	MM - Closed system	4.37	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Coating	MM - Closed system	16	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Coating	MM - Closed system	6.5	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Coating	MM - Closed system	0.5	L	No	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Coating	MM - Closed system	0.4	L	No	-
7320-34-5	Tetrapotassium pyrophosphate	Maintenance - Coating	MM - Closed system	98	L	-	-
13463-67-7	Titanium dioxide	Maintenance - Coating	MM - Closed system	4.37	L	-	-
13463-67-7	Titanium dioxide	Maintenance - Coating	MM - Closed system	0.5	L	-	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	3.75	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	135	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	1.25	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	16	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	60	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	6.5	L	No	-
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	0.8	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
1330-20-7	Xylene	Maintenance - Coating	MM - Closed system	0.5	L	No	-
7440-66-6	zinc	Maintenance - Coating	MM - Closed system	16	L	No	-
7440-66-6	zinc	Maintenance - Coating	MM - Closed system	0.8	L	No	-
7440-66-6	zinc	Maintenance - Coating	MM - Closed system	0.5	L	No	-
101-68-8	4,4'-methylenediphenyl diisocyanate	Maintenance - Glue	MM - Closed system	as required		No	-
1330-20-7	Xylene	Maintenance - Glue	MM - Closed system	as required		No	-
81-07-2	1,2-benzisothiazol-3(2H)-one 1,1-dioxide	Maintenance - Other	MM - Closed system	0.1	L	-	-
39382-25-7	2-Butenedioic acid (2E)-, polymer with α,α'-[(1-methylethylidene)di-4,1-phenylene]bis[ω-hydroxypoly[oxy(methyl-1,2-ethanediyl)]]	Maintenance - Other	MM - Closed system	0.1	L	-	-
114-83-0	2'-phenylacetohydrazide	Maintenance - Other	MM - Closed system	0.08	L	-	-
66204-44-2	3,3'-methylenebis[5-methyloxazolidine]	Maintenance - Other	MM - Closed system	1	L	No	-
25068-38-6	4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane	Maintenance - Other	MM - Closed system	41	L	No	-
68609-93-8	9-Octadecenoic acid (Z)-, sulfonated, potassium salts	Maintenance - Other	MM - Closed system	1	L	No	-
64-19-7	Acetic acid	Maintenance - Other	MM - Closed system	32	L	No	PLONOR
64-19-7	Acetic acid	Maintenance - Other	MM - Closed system	30	L	No	PLONOR

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
67-64-1	Acetone	Maintenance - Other	MM - Closed system	0.8	L	No	-
67-64-1	Acetone	Maintenance - Other	MM - Closed system	4.5	L	No	-
1327-36-2	Aluminatesilicate	Maintenance - Other	MM - Closed system	1	kg	-	-
90989-38-1	Aromatic hydrocarbons, C8	Maintenance - Other	MM - Closed system	4.5	L	-	-
71-36-3	Butan-1-ol	Maintenance - Other	MM - Closed system	41	L	No	PLONOR
78-93-3	Butanone	Maintenance - Other	MM - Closed system	0.8	L	No	-
124-38-9	Carbon dioxide	Maintenance - Other	MM - Closed system	as required	-	-	-
7440-50-8	Copper	Maintenance - Other	MM - Closed system	0.11	kg	-	-
1309-37-1	Diiron trioxide	Maintenance - Other	MM - Closed system	1	L	-	PLONOR
115-10-6	Dimethyl ether	Maintenance - Other	MM - Closed system	4.5	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Maintenance - Other	MM - Closed system	as required	-	No	-
64742-47-8	Distillates (petroleum), hydrotreated light	Maintenance - Other	MM - Closed system	as required	-	No	-
64742-47-8	Distillates (petroleum), hydrotreated light	Maintenance - Other	MM - Closed system	as required	-	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Maintenance - Other	MM - Closed system	as required	-	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Maintenance - Other	MM - Closed system	as required	-	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Maintenance - Other	MM - Closed system	as required	-	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Maintenance - Other	MM - Closed system	0.11	kg	No	-
142-90-5	Dodecyl methacrylate	Maintenance - Other	MM - Closed system	0.08	L	No	-
64-17-5	Ethanol	Maintenance - Other	MM - Closed system	1260	pcs	No	PLONOR
2495-27-4	Hexadecyl methacrylate	Maintenance - Other	MM - Closed system	0.08	L	No	-
1333-74-0	Hydrogen	Maintenance - Other	MM - Closed system	1	pcs	-	-
7664-39-3	Hydrogen fluoride	Maintenance - Other	MM - Closed system	12	kg	-	-
7664-39-3	Hydrogen fluoride	Maintenance - Other	MM - Closed system	2.7	kg	-	-
75-28-5	Isobutane	Maintenance - Other	MM - Closed system	2.4	L	No	-
10377-60-3	Magnesium nitrate	Maintenance - Other	MM - Closed system	as required	-	-	-
110-16-7	Maleic acid Maleic acid	Maintenance - Other	MM - Closed system	0.08	L	No	-
4253-34-3	Methylsilanetriyl triacetate	Maintenance - Other	MM - Closed system	0.1	L	-	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Maintenance - Other	MM - Closed system	0.4	L	No	-
7697-37-2	Nitric acid	Maintenance - Other	MM - Closed system	2.7	kg	-	-
7697-37-2	Nitric acid	Maintenance - Other	MM - Closed system	12	kg	-	-
64742-71-8	Paraffin oils (petroleum), catalytic dewaxed light	Maintenance - Other	MM - Closed system	as required	-	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68476-86-8	Petroleum gases, liquefied, sweetened	Maintenance - Other	MM - Closed system	0.4	L	No	-
71-23-8	Propan-1-ol	Maintenance - Other	MM - Closed system	1260	pcs	No	PLONOR
67-63-0	Propan-2-ol	Maintenance - Other	MM - Closed system	1260	pcs	No	PLONOR
74-98-6	Propane	Maintenance - Other	MM - Closed system	1	L	No	-
74-98-6	Propane	Maintenance - Other	MM - Closed system	4.5	L	No	-
57-55-6	Propane-1,2-diol	Maintenance - Other	MM - Closed system	0.1	L	No	-
68909-20-6	Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-, hydrolysis products with silica	Maintenance - Other	MM - Closed system	0.1	L	-	-
1338-43-8	Sorbitan oleate	Maintenance - Other	MM - Closed system	2.4	L	-	-
61789-86-4	Sulfonic acids, petroleum, calcium salts	Maintenance - Other	MM - Closed system	as required	-	No	-
2549-53-3	Tetradecyl methacrylate	Maintenance - Other	MM - Closed system	0.08	L	No	-
13463-67-7	Titanium dioxide	Maintenance - Other	MM - Closed system	0.1	L	-	-
17689-77-9	Triacetoxyethylsilane	Maintenance - Other	MM - Closed system	0.1	L	No	-
1330-20-7	Xylene	Maintenance - Other	MM - Closed system	4.5	L	No	-
1330-20-7	Xylene	Maintenance - Other	MM - Closed system	41	L	No	-
7440-66-6	zinc	Maintenance - Other	MM - Closed system	4.5	L	No	-
25254-50-6	α,α',α''-trimethyl-1,3,5-triazine-1,3,5(2H,4H,6H)-triethanol	Maintenance - Other	MM - Closed system	1	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-48-9	Hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics	Maintenance - Other machine media	MM - Closed system	as required	-	No	-
68608-26-4	Sulfonic acids, petroleum, sodium salts	Maintenance - Other machine media	MM - Closed system	as required	-	No	-
108-03-2	1-nitropropane	Other	MM - Closed system	4.5	L	No	-
102-71-6	2,2',2''-nitrilotriethanol	Other	MM - Closed system	1	L	No	-
90-72-2	2,4,6-tris(dimethylaminomethyl)phenol	Other	MM - Closed system	-	-	No	-
25068-38-6	4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane	Other	MM - Closed system	-	-	No	-
106-97-8	Butane	Other	MM - Closed system	1	L	No	-
106-97-8	Butane	Other	MM - Closed system	4.5	L	No	-
100-41-4	Ethylbenzene	Other	MM - Closed system	41	L	-	-
9003-36-5	Formaldehyde, oligomeric reaction products with 1-chloro-2,3-epoxypropane and phenol	Other	MM - Closed system	-	-	No	-
10377-60-3	Magnesium nitrate	Other	MM - Closed system	12	kg	-	-
67-64-1	Acetone	Maintenance - Other	MM-Closed system	0.04 l	-	No	-
115-10-6	Dimethyl ether	Maintenance - Other	MM-Closed system	0.04 l	-	No	-
63800-37-3	Sepiolite	Maintenance - Other	MM-Closed system	as required	-	-	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Maintenance - Other	MM-Closed system	0.04 l	-	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
1330-20-7	Xylene	Maintenance - Other	MM-Closed system	0.04 l	-	No	-
7440-66-6	zinc	Maintenance - Other	MM-Closed system	0.04 l	-	No	-
34590-94-8	(2-methoxymethylethoxy)propanol	Fire protection	OM - Accidents	135	L	No	-
5131-66-8	1-butoxypropan-2-ol	Fire protection	OM - Accidents	200	L	No	-
5131-66-8	1-butoxypropan-2-ol	Fire protection	OM - Accidents	200	L/OS S	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	795	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	400	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	3000	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	400	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	as required	-	No	-
4719-04-4	2,2',2''-(hexahydro-1,3,5-triazine-1,3,5-triyl)triethanol	Fire protection	OM - Accidents	240	L	No	-
107-41-5	2-methylpentane-2,4-diol	Fire protection	OM - Accidents	240	L	No	-
7722-76-1	Ammonium dihydrogenorthophosphate	Fire protection	OM - Accidents	45	kg	-	PLONOR
124-38-9	Carbon dioxide	Fire protection	OM - Accidents	-	-	-	-
124-38-9	Carbon dioxide	Fire protection	OM - Accidents	-	-	-	-
124-38-9	Carbon dioxide	Fire protection	OM - Accidents	18	kg	-	-
68515-73-1	D-Glucopyranose, oligomers, decyl octyl glycosides	Fire protection	OM - Accidents	200	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68515-73-1	D-Glucopyranose, oligomers, decyl octyl glycosides	Fire protection	OM - Accidents	200	L	No	-
68515-73-1	D-Glucopyranose, oligomers, decyl octyl glycosides	Fire protection	OM - Accidents	400	L	No	-
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	795	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	400	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	3000	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	200	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	200	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	400	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Fire protection	OM - Accidents	as required	-	No	PLONOR
57-55-6	Propane-1,2-diol	Fire protection	OM - Accidents	135	L	No	-
7647-14-5	Sodium chloride	Fire protection	OM - Accidents	240	L	No	PLONOR
142-31-4	sodium octyl sulfate	Fire protection	OM - Accidents	795	L	No	-
142-31-4	sodium octyl sulfate	Fire protection	OM - Accidents	3000	L	No	-
142-31-4	sodium octyl sulfate	Fire protection	OM - Accidents	200	l	No	-
142-31-4	sodium octyl sulfate	Fire protection	OM - Accidents	200	L	No	-
142-31-4	sodium octyl sulfate	Fire protection	OM - Accidents	400	L	No	-
67762-26-6	Fatty acids, C14-18 and C16-18-unsatd., Me esters	Fuel	OM - Accidents	200390	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
67762-26-9	Fatty acids, C14-18 and C16-18-unsatd., Me esters	Fuel	OM - Accidents	150000	L	No	-
68990-52-3	Fatty acids, vegetable-oil, Me esters	Fuel	OM - Accidents	89000	L	No	-
68476-33-5	Fuel oil, residual	Fuel	OM - Accidents	27100	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	150000	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	TOTAL 12000	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	244500	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	-	-	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	TOTAL. 22000	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	200390	L	No	-
68334-30-5	Fuels, diesel	Fuel	OM - Accidents	-	-	No	-
68476-34-6	Fuels, diesel, no. 2	Fuel	OM - Accidents	89000	L	No	-
8008-20-6	Kerosine (petroleum)	Fuel	OM - Accidents	6x2000	L	No	-
8008-20-6	Kerosine (petroleum)	Fuel	OM - Accidents	6x2000	L	No	-
7704-34-9	Sulfur	Fuel	OM - Accidents	27100	L	-	-
68425-15-0	Polysulfides, di-tert-dodecyl	Grease	OM - Accidents	0.5	L	No	-
EC: 939-455-3	1-Propanaminium, N-(3-aminopropyl)-2-hydroxy-N,N-dimethyl-3-sulfo-, N-(C8-18(even numbered) acyl) derivs.,	Fire protection	OM - Accidents	50	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
	hydroxides, inner salts EC number: 939-455-3 | CAS number: -						
112-34-5	2-(2-butoxyethoxy)ethanol	Fire protection	OM - Accidents	50	L	No	-
68515-73-1	D-Glucopyranose, oligomers, decyl octyl glycosides	Fire protection	OM - Accidents	50	L	No	-
65997-15-1	Portland cement	Other	OM - Accidents	866000	L	-	PLONOR
68334-30-5	Fuels, diesel		OM - Accidents	TOTAL 226840	L	No	-
12179-04-3	Disodium tetraborate, anhydrous	Antifreeze	OM - Closed system	630	L	-	-
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	1840	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	32	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	17650	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	TOTAL 4440	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	46	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	900	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Antifreeze	OM - Closed system	630	L	No	PLONOR
57-55-6	Propane-1,2-diol	Antifreeze	OM - Closed system	800	kg	No	-
19766-89-3	Sodium 2-ethylhexanoate	Antifreeze	OM - Closed system	900	L	No	-
19766-89-3	Sodium 2-ethylhexanoate	Antifreeze	OM - Closed system	630	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
9003-56-9	2-Propenenitrile, polymer with 1,3-butadiene and ethenylbenzene	Batteries	OM - Closed system	260	pcs	-	-
7440-70-2	Calcium	Batteries	OM - Closed system	260	pcs	-	-
65997-17-3	Glass oxide (silicon(4+) dialuminium(3+) diboron(3+) octaoxidandiide)	Batteries	OM - Closed system	2	pcs	-	-
65997-17-3	Glass oxide (silicon(4+) dialuminium(3+) diboron(3+) octaoxidandiide)	Batteries	OM - Closed system	-	-	-	-
65997-17-3	Glass oxide (silicon(4+) dialuminium(3+) diboron(3+) octaoxidandiide)	Batteries	OM - Closed system	8	pcs	-	-
9010-79-1	Polypropylene copolymer	Batteries	OM - Closed system	2	pcs	-	-
9010-79-1	Polypropylene copolymer	Batteries	OM - Closed system	-	-	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	260	pcs	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	2	pcs	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	2	pcs	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	-	-	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	52	pcs	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	15768	kg	-	-
7664-93-9	Sulphuric acid	Batteries	OM - Closed system	TOTAL 183.6	kg	-	-
7440-31-5	Tin	Batteries	OM - Closed system	260	pcs	-	-
111-46-6	2,2'-oxydiethanol	Coolant	OM - Closed system	TOTAL 1895	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
149-57-5	2-ethylhexanoic acid	Coolant	OM - Closed system	TOTAL 1895	L	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	TOTAL 263.4	kg	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	190	kg	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	TOTAL 460	kg	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	50	kg	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	395	kg	No	-
12179-04-3	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	450	L	-	-
1330-43-4	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	580	L	-	-
1330-43-4	Disodium tetraborate, anhydrous	Coolant	OM - Closed system	-	-	-	-
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	660	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	3	-	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	195 l	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	TOTAL 189l	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	-	-	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	1840	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	580	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	400	LL	No	PLONOR

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	44	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	-	-	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	1840	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	301500	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	450	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	450	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Coolant	OM - Closed system	-	-	No	PLONOR
10377-60-3	Magnesium nitrate	Coolant	OM - Closed system	-	-	-	-
811-97-2	Norflurane	Coolant	OM - Closed system	TOTAL 263.4	kg	No	-
811-97-2	Norflurane	Coolant	OM - Closed system	396	kg	No	-
811-97-2	Norflurane	Coolant	OM - Closed system	-	-	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	TOTAL 263.4	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	190	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	460	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	50	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	395	kg	No	-
1310-58-3	Potassium hydroxide	Coolant	OM - Closed system	TOTAL 1895	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
57-55-6	Propane-1,2-diol	Coolant	OM - Closed system	500	L	No	-
19766-89-3	Sodium 2-ethylhexanoate	Coolant	OM - Closed system	-	-	No	-
19766-89-3	Sodium 2-ethylhexanoate	Coolant	OM - Closed system	450	L	No	-
19766-89-3	Sodium 2-ethylhexanoate Sodium 2-ethylhexanoate	Coolant	OM - Closed system	44	L	No	-
7722-76-1	Ammonium dihydrogenorthophosphate	Fire protection	OM - Closed system	1206	kg	-	PLONOR
7440-37-1	Argon	Fire protection	OM - Closed system	1320	kg	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	1400	kg	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	-	-	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	-	-	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	8960	L	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	-	-	-	-
7440-37-1	Argon	Fire protection	OM - Closed system	-	-	-	-
10043-52-4	calcium dichloride	Fire protection	OM - Closed system	45	L	-	PLONOR
124-38-9	Carbon dioxide	Fire protection	OM - Closed system	670	kg	-	-
124-38-9	Carbon dioxide	Fire protection	OM - Closed system	79.1	kg	-	-
124-38-9	Carbon dioxide	Fire protection	OM - Closed system	-	-	-	-
124-38-9	Carbon dioxide	Fire protection	OM - Closed system	-	-	-	-
107-21-1	Ethane-1,2-diol	Fire protection	OM - Closed system	45	L	No	PLONOR
7727-37-9	Nitrogen	Fire protection	OM - Closed system	1320	kg	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
7727-37-9	Nitrogen	Fire protection	OM - Closed system	1400	kg	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	-	-	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	-	-	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	-	-	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	8960	L	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	-	-	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	-	-	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	1115	kg	-	-
7727-37-9	Nitrogen	Fire protection	OM - Closed system	2844	kg	-	-
142-31-4	sodium octyl sulfate	Fire protection	OM - Closed system	45	L	No	-
68334-30-5	Fuels, diesel (during installation phase)	Fuel	OM - Closed system	500	L	No	-
8008-20-6	Kerosine (petroleum)	Fuel	OM - Closed system	8700	kg	No	-
64742-81-0	Kerosine (petroleum), hydrodesulfurized	Fuel	OM - Closed system	8700	kg	No	-
91770-15-9	Kerosine (petroleum), sweetened	Fuel	OM - Closed system	8700	kg	No	-
928771-01-1	Renewable hydrocarbons (diesel type fraction)	Fuel	OM - Closed system	2750	L	No	-
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Gear Oil	OM - Closed system	2	kg	No	-
115733-10-3	Benzenesulfonic acid, C14-24-branched and linear alkyl derivatives, calcium salts, overbased	Gear Oil	OM - Closed system	-	L	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
115733-10-3	Benzenesulfonic acid, C14-24-branched and linear alkyl derivatives, calcium salts, overbased	Gear Oil	OM - Closed system	820.4	L	-	-
115733-10-3	Benzenesulfonic acid, C14-24-branched and linear alkyl derivatives, calcium salts, overbased	Gear Oil	OM - Closed system	10720	L	-	-
16958-92-2	Bis(tridecyl) adipate	Gear Oil	OM - Closed system	1474	L	-	-
16958-92-2	Bis(tridecyl) adipate	Gear Oil	OM - Closed system	1474	L	-	-
64742-80-9	Distillates (petroleum), hydrodesulfurized middle	Gear Oil	OM - Closed system	800	L	No	-
597-82-0	O,O,O-triphenyl phosphorothioate	Gear Oil	OM - Closed system	1474	L	No	-
597-82-0	O,O,O-triphenyl phosphorothioate	Gear Oil	OM - Closed system	1474	L	No	-
8052-42-4	Asphalt	Grease	OM - Closed system	0.16	kg	No	-
25619-56-1	Barium bis(dinonylnaphthalenesulphonate)	Grease	OM - Closed system	0.06	kg	-	-
25619-56-1	Barium bis(dinonylnaphthalenesulphonate)	Grease	OM - Closed system	0.35	kg	-	-
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Grease	OM - Closed system	140	L	No	-
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Grease	OM - Closed system	1.06	kg	No	-
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Grease	OM - Closed system	140	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Grease	OM - Closed system	9380	L	No	-
85117-41-5	Benzene, mono-C10-14-alkyl derivs., fractionation bottoms	Grease	OM - Closed system	6	L	-	-
85117-47-1	Benzene, mono-C10-14-alkyl derivs., fractionation bottoms, intermediate cut, sulfonated, sodium salts	Grease	OM - Closed system	5	kg	No	-
939-603-7	Benzenesulfonic acid, di-C10-14-alkyl derivs., calcium salts	Grease	OM - Closed system	5	kg	No	-
68649-11-6	Dec-1-ene, dimers, hydrogenated	Grease	OM - Closed system	-	-	No	-
68649-11-6	Dec-1-ene, dimers, hydrogenated	Grease	OM - Closed system	15	L	No	-
68649-11-6	Dec-1-ene, dimers, hydrogenated	Grease	OM - Closed system	12	L	No	-
1330-43-4	Disodium tetraborate, anhydrous	Grease	OM - Closed system	30	L	-	-
107-21-1	Ethane-1,2-diol	Grease	OM - Closed system	30	L	No	PLONOR
72102-30-8	Fatty acids, vegetable-oil, Me esters, sulfurized	Grease	OM - Closed system	7	L	No	-
72102-30-8	Fatty acids, vegetable-oil, Me esters, sulfurized	Grease	OM - Closed system	6	L	No	-
68919-17-5	Hydrocarbons, C12-20, catalytic alkylation by-products	Grease	OM - Closed system	6	L	-	-
1310-65-2	Lithium hydroxide	Grease	OM - Closed system	7	L	-	-
85736-59-0	Naphthenic acids, bismuth salts	Grease	OM - Closed system	0.2	kg	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-70-7	Paraffin oils (petroleum), catalytic dewaxed heavy	Grease	OM - Closed system	6	L	No	-
68425-15-0	Polysulfides, di-tert-dodecyl	Grease	OM - Closed system	6	kg	No	-
19766-89-3	Sodium 2-ethylhexanoate	Grease	OM - Closed system	30	L	No	-
64742-88-7	Solvent naphtha (petroleum), medium aliph.	Grease	OM - Closed system	6	L	No	-
1330-20-7	Xylene	Grease	OM - Closed system	6	L	No	-
16958-92-2	Bis(tridecyl) adipate	Hydraulic oil	OM - Closed system	240	L	-	-
16958-92-2	Bis(tridecyl) adipate	Hydraulic oil	OM - Closed system	240	L	-	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Hydraulic oil	OM - Closed system	2x 30	L	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Hydraulic oil	OM - Closed system	2x 1500	L	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Hydraulic oil	OM - Closed system	-	-	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Hydraulic oil	OM - Closed system	1100	L	No	-
57855-77-3	calcium bis(di C8-C10, branched, C9 rich, alkylnaphthalenesulphonate)	Hydraulic oil	OM - Closed system	52	L	No	-
57855-77-3	calcium bis(di C8-C10, branched, C9 rich, alkylnaphthalenesulphonate)	Hydraulic oil	OM - Closed system	240	L	No	-
68037-01-4	Dec-1-ene, homopolymer, hydrogenated Dec-1-ene, oligomers, hydrogenated	Hydraulic oil	OM - Closed system	2x 30	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68037-01-4	Dec-1-ene, homopolymer, hydrogenated Dec-1-ene, oligomers, hydrogenated	Hydraulic oil	OM - Closed system	2x 1500	L	No	-
68037-01-4	Dec-1-ene, homopolymer, hydrogenated Dec-1-ene, oligomers, hydrogenated	Hydraulic oil	OM - Closed system	1100	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	60	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	3000	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	-	-	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	31.6	L	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	-	-	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Hydraulic oil	OM - Closed system	1100	L	No	-
265-156-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	2.4	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	60	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	2.4	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	3000	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	1100	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Hydraulic oil	OM - Closed system	60	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Hydraulic oil	OM - Closed system	3000	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Hydraulic oil	OM - Closed system	0.5	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Hydraulic oil	OM - Closed system	950	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Hydraulic oil	OM - Closed system	1100	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	60	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	3000	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	31.6	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	-	-	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	1100	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	403	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	600	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	600	L/OS S	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	730	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	60	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	3000	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	13	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	18.6	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	200 + 530	L	No	-
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Hydraulic oil	OM - Closed system	1100	L	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	60	L	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	3000	L	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	1100	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	730	L	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	60	L	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	3000	L	No	-
72623-87-13	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Hydraulic oil	OM - Closed system	1100	L	No	-
597-82-0	O,O,O-triphenyl phosphorothioate	Hydraulic oil	OM - Closed system	240	L	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Insulating gas/fluid	OM - Closed system	2x 49000	kg	No	-
64742-52-5	Distillates (petroleum), hydrotreated heavy naphthenic	Insulating gas/fluid	OM - Closed system		See MSD S	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	110300	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	2x134060	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	55710	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	-	-	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Insulating gas/fluid	OM - Closed system	226600	kg	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Insulating gas/fluid	OM - Closed system	-	-	No	-
64741-96-4	Distillates (petroleum), solvent-refined heavy naphthenic	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
64741-97-5	Distillates (petroleum), solvent-refined light naphthenic	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	15230	kg	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	1800	kg	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	8	t	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	5500	L	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	147400	kg	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	500	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	1200	kg	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Insulating gas/fluid	OM - Closed system	1800	kg	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Insulating gas/fluid	OM - Closed system	TOTAL 17380	kg	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Insulating gas/fluid	OM - Closed system	226600	kg	No	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	849.4	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	4,8	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	2440	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	4.4	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	449	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	365	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	4.4	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	251.6	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	-	-	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	-	-	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	4.4	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	998	kg	-	-
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	644	kg	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
2551-62-4	Sulphur hexafluoride	Insulating gas/fluid	OM - Closed system	2647	kg	-	-
7429-90-5	aluminium	Lubricant	OM - Closed system	5	kg	-	-
36878-20-3	Bis(nonylphenyl)amine	Lubricant	OM - Closed system	-	-	No	-
16958-92-2	Bis(tridecyl) adipate	Lubricant	OM - Closed system	1897	L	-	-
16958-92-2	Bis(tridecyl) adipate	Lubricant	OM - Closed system	1897	L	-	-
106-97-8	Butane	Lubricant	OM - Closed system	0,3	kg	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Lubricant	OM - Closed system	1 l	L	No	-
7440-50-8	Copper	Lubricant	OM - Closed system	5	kg	-	-
68037-01-4	Dec-1-ene, homopolymer, hydrogenated Dec-1-ene, oligomers, hydrogenated	Lubricant	OM - Closed system	1 l	L	No	-
12007-60-2	Dilithium tetraborate	Lubricant	OM - Closed system	0.3	kg	-	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Lubricant	OM - Closed system	1	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Lubricant	OM - Closed system	1	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Lubricant	OM - Closed system	1	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Lubricant	OM - Closed system	1	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Lubricant	OM - Closed system	21	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-56-9	Distillates (petroleum), solvent-dewaxed light paraffinic	Lubricant	OM - Closed system	1	L	No	-
64741-96-4	Distillates (petroleum), solvent-refined heavy naphthenic	Lubricant	OM - Closed system	30	L	No	-
72102-30-8	Fatty acids, vegetable-oil, Me esters, sulfurized	Lubricant	OM - Closed system	6	L	No	-
72102-30-8	Fatty acids, vegetable-oil, Me esters, sulfurized	Lubricant	OM - Closed system	7	L	No	-
72102-30-8	Fatty acids, vegetable-oil, Me esters, sulfurized	Lubricant	OM - Closed system	469	L	No	-
7782-42-5	Graphite	Lubricant	OM - Closed system	5	kg	-	PLONOR
75-28-5	Isobutane	Lubricant	OM - Closed system	0.3	kg	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Lubricant	OM - Closed system	1	L	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Lubricant	OM - Closed system	1	L	No	-
64742-49-0	Naphtha (petroleum), hydrotreated light	Lubricant	OM - Closed system	0.3	kg	No	-
597-82-0	O,O,O-triphenyl phosphorothioate	Lubricant	OM - Closed system	1897	L	No	-
90480-91-4	Phenol, 2,2'-polythiobis[4-C8-30-alkyl derivs., calcium salts	Lubricant	OM - Closed system	1350	L	-	-
68425-15-0	Polysulfides, di-tert-dodecyl	Lubricant	OM - Closed system	30	L	No	-
74-98-6	Propane	Lubricant	OM - Closed system	0.3	kg	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-62-7	Residual oils (petroleum), solvent-dewaxed	Lubricant	OM - Closed system	-	-	No	-
64742-01-4	Residual oils (petroleum), solvent-refined	Lubricant	OM - Closed system	30	L	No	-
111-76-2	2-butoxyethanol	Maintenance - Coating	OM - Closed system	0.3	kg	No	-
64742-48-9	Hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics	Maintenance - Coating	OM - Closed system	0.3	kg	No	-
68608-26-4	Sulfonic acids, petroleum, sodium salts	Maintenance - Coating	OM - Closed system	0.3	kg	No	-
6834-92-0	Disodium metasilicate	Maintenance - Other	OM - Closed system	5	L	-	PLONOR
5949-29-1	Citric acid	Maintenance - Other	OM - Closed system	4.76	kg/a	No	-
107-21-1	Ethane-1,2-diol	Maintenance - Other	OM - Closed system	30	L	No	PLONOR
107-21-1	Ethane-1,2-diol	Maintenance - Other	OM - Closed system	30	L	No	PLONOR
9043-30-5	Isotridecylalcohol, ethoxylated	Maintenance - Other	OM - Closed system	5	L	-	-
1310-58-3	Potassium hydroxide	Maintenance - Other	OM - Closed system	3.57	kg/a	-	-
1310-58-3	Potassium hydroxide	Maintenance - Other	OM - Closed system	5	L	-	-
67-63-0	Propan-2-ol	Maintenance - Other	OM - Closed system	5	L	No	PLONOR
126-92-1	Sodium etasulfate	Maintenance - Other	OM - Closed system	5	L	No	-
7320-34-5	Tetrapotassium pyrophosphate	Maintenance - Other	OM - Closed system	3.57	kg/a	-	-
1330-20-7	Xylene	Maintenance - Other	OM - Closed system	as required	-	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
68515-49-1	1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich	Lubricant	OM - Closed system	80	L	No	-
883233-48-5	Alkene, polymer with 1-dodecene, distn. Residues, hydrogenated, C24-56 fraction	Lubricant	OM - Closed system	80	L	-	-
7440-37-1	Argon	Other	OM - Closed system	18.7	kg	-	-
68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	Hydraulic oil	OM - Closed system	20	L	No	-
70024-69-0	Benzenesulfonic acid, mono-C16-24-alkyl derivs., calcium salts	Transformer oil	OM - Closed system	20	L	-	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Transformer oil	OM - Closed system	40	L	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Transformer oil	OM - Closed system	10400	L	No	-
848301-69-9	C18-C50 branched, cyclic and linear hydrocarbons – Distillates	Transformer oil	OM - Closed system	40	L	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	90.4	kg	No	-
75-10-5	Difluoromethane	Coolant	OM - Closed system	45.2	kg	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Transformer oil	OM - Closed system	182000	kg	No	-
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Gear Oil	OM - Closed system	20	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Transformer oil	OM - Closed system	182000	kg	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Hydraulic oil	OM - Closed system	20	L	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Transformer oil	OM - Closed system	182000	kg	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Gear Oil	OM - Closed system	40	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Hydraulic oil	OM - Closed system	16	kg	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Gear Oil	OM - Closed system	40	L	No	-
1333-74-0	Hydrogen	Other	OM - Closed system	20	kg	-	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	182000	kg	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	182000	kg	No	-
7727-37-9	Nitrogen	Other	OM - Closed system	3.6	L	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	120	L	-	-
811-97-2	Norflurane	Coolant	OM - Closed system	136	kg	No	-
811-97-2	Norflurane	Coolant	OM - Closed system	90.4	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	90.4	kg	No	-
354-33-6	Pentafluoroethane	Coolant	OM - Closed system	45.2	kg	No	-
74-98-6	Propane	Other	OM - Closed system	60.3	kg	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
57-55-6	Propane-1,2-diol	Other	OM - Closed system	168	L	No	-
68784-17-8	Reaction products of fatty acids, C14-C18 (branched and linear) and C18 (unsaturated) with tetraethylenepentamine (linear, branched, cyclic)	Gear Oil	OM - Closed system	20	L	No	-
136-53-8	Zinc bis(2-ethylhexanoate)	Grease	OM - Closed system	19.6	kg	-	-
112-34-5	2-(2-butoxyethoxy)ethanol	Other	OM - Closed system	5l	L	No	-
266-235-8	3,3'-methylenebis[5-methyloxazolidine]	Other	OM - Closed system	1.8	L	No	-
67-64-1	Acetone	Other	OM - Closed system	as required	-	No	-
68439-46-3	Alcohols, C9-11, ethoxylated	Other	OM - Closed system	5l	L	No	-
97043-91-9	Alcohols, C9-16, ethoxylated	Other	OM - Closed system	0	0	-	-
7429-90-5	aluminium	Other	OM - Closed system	10	pcs	-	-
10022-31-8	Barium nitrate	Other	OM - Closed system	10	pcs	-	-
67774-74-7	Benzene, C10-13-alkyl derivs	Other	OM - Closed system	1.8	L	No	-
471-34-1	Calcium carbonate	Other	OM - Closed system	-	-	-	PLONOR
115-10-6	Dimethyl ether	Other	OM - Closed system	as required	-	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Other	OM - Closed system	1200	kg	No	-
7439-95-4	Magnesium	Other	OM - Closed system	10	pcs	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
7727-37-9	Nitrogen	Other	OM - Closed system	63600	L	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	30	kg	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	2160	L	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	80	kg	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	2160	L	-	-
7727-37-9	Nitrogen	Other	OM - Closed system	4261200	L	-	-
7757-79-1	Potassium nitrate	Other	OM - Closed system	10	pcs	-	PLONOR
7778-74-7	Potassium perchlorate	Other	OM - Closed system	10	pcs	-	-
63800-37-3	Sepiolite	Other	OM - Closed system	as required	-	-	-
64742-95-6	Solvent naphtha (petroleum), light arom.	Other	OM - Closed system	as required	-	No	-
10042-76-9	Strontium nitrate	Other	OM - Closed system	10	pcs	-	-
7704-34-9	Sulfur	Other	OM - Closed system	10	pcs	-	-
7440-66-6	zinc	Other	OM - Closed system	as required	-	No	-
93820-52-1	β-Alanine, N-(2-aminoethyl)-N-(2-hydroxyethyl)-, N-coco acyl derivs., monosodium salts	Other	OM - Closed system	5l	L	-	-
64742-48-9	Hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics	Other machine media	OM - Closed system	1.5	L	No	-
68608-26-4	Sulfonic acids, petroleum, sodium salts	Other machine media	OM - Closed system	1.5	L	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
64742-54-7	Distillates (petroleum), hydrotreated heavy paraffinic	Transformer oil	OM - Closed system	23000	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Transformer oil	OM - Closed system	23000	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Transformer oil	OM - Closed system	100000	kg	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Transformer oil	OM - Closed system	4377	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic	Transformer oil	OM - Closed system	112000	kg	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Transformer oil	OM - Closed system	23000	kg	No	-
64742-55-8	Distillates (petroleum), hydrotreated light paraffinic	Transformer oil	OM - Closed system	4377	L	No	-
64742-65-0	Distillates (petroleum), solvent-dewaxed heavy paraffinic	Transformer oil	OM - Closed system	4377	L	No	-
64741-96-4	Distillates (petroleum), solvent-refined heavy naphthenic	Transformer oil	OM - Closed system	4377	L	No	-
64741-89-5	Distillates (petroleum), solvent-refined light paraffinic 5-butyl-10-propyltetradecane	Transformer oil	OM - Closed system	4377	L	No	-
68424-31-7	Fatty acids, C5-10, esters with pentaerythritol	Transformer oil	OM - Closed system	8800	kg	No	-
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	23000	kg	No	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
72623-86-0	Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	4377	L	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	23000	kg	No	-
72623-87-1	Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	Transformer oil	OM - Closed system	4377	L	No	-
112-34-5	2-(2-butoxyethoxy)ethanol		OM - Closed system	200	L	No	-
107-41-5	2-methylpentane-2,4-diol		OM - Closed system	200	L	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic		OM - Closed system	2x12.6	t	No	-
64742-53-6	Distillates (petroleum), hydrotreated light naphthenic		OM - Closed system	33000	L	No	-
7727-37-9	Nitrogen		OM - Closed system	-	-	-	-
68439-45-2	Alcohols, C6-12, ethoxylated	Other	Open system	40	L	-	-
132778-08-06	C9-11-Alkyl D-Glycopyranoside, Decyl/undecyl glucosides	Other	Open system	165	L	-	-
26264-05-1	Dodecylbenzenesulphonic acid, compound with isopropylamine (1:1)	Other	Open system	40	L	-	-
7320-34-5	Tetrapotassium pyrophosphate	Other	Open system	165	L	-	-
101-68-8	4,4'-methylenediphenyl diisocyanate	Other	Open system	240	L	No	-
1305-62-0	Calcium dihydroxide	Other	Open system	-	-	-	PLONOR
1305-78-8	Calcium oxide	Other	Open system	5500	L	-	PLONOR

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
1305-78-8	Calcium oxide	Other	Open system	-	-	-	PLONOR
1305-78-8	Calcium oxide	Other	Open system	83800	L	-	PLONOR
69012-64-2	Fumes, silica	Other	Open system			-	-
65997-15-1	Portland cement	Other	Open system	15000	L	-	PLONOR
65997-15-1	Portland cement	Other	Open system			-	PLONOR
65997-15-1	Portland cement	Other	Open system	5500	L	-	PLONOR
65997-15-1	Portland cement	Other	Open system	-	-	-	PLONOR
65997-15-1	Portland cement	Other	Open system	83800	L	-	PLONOR
65997-15-1	Portland cement	Other	Open system	4480000	L	-	PLONOR
65997-15-1	Portland cement	Other	Open system	280000	L	-	PLONOR
1310-73-2	Sodium hydroxide	Other	Open system	-	-	-	-
64-02-8	Tetrasodium ethylenediaminetetraacetate (EDTA)	Other	Open system	-	-	No	-
1330-20-7	Xylene	Other	Open system	240	L	No	-
7429-90-5	Aluminium	Sacrificial anodes	Open System	See report on corrosion protectio n	-	-	-
7439-89-6	Copper	Sacrificial anodes	Open System	See report on corrosion	-	-	-

CAS nr	Substance	Type of operating material	Open/closed system	Volume	Unit	PBT criteria	Occurrence on substance classification list
				protectio n			
7440-21-3	Silicium	Sacrificial anodes	Open System	See report on corrosion protectio n	-	-	-
7440-66-6	Zink	Sacrificial anodes	Open System	See report on corrosion protectio n	-	No	-
14798-03-9	Ammonium	Wastewater Treatment	Open System	No informati on	-	-	-
14797-55-8	Nitrate	Wastewater Treatment	Open System	No informati on	-	-	-
14797-65-0	Nitrite	Wastewater Treatment	Open System	No informati on	-	-	-