Baltic Marine Environment Protection Commission

Expert Group on Environmental Risks of Hazardous Submerged Objects
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Background

In accordance with the Terms of Reference agreed by HELCOM HOD 43-2013, the Expert Group on Environmental Risks of Hazardous Submerged Objects is to produce a HELCOM Thematic Assessment on Hazardous Submerged Objects. SUBMERGED 6-2018 agreed that an interim HELCOM Submerged Assessment should be submitted to RESPONSE 25-2018 (14 to 16 November 2018), and subsequently to HELCOM HOD 55-2018 in December 2018 for approval. For this purpose, a draft text on submerged warfare materials in the Baltic Sea is set out in the annex.

Action requested

The Meeting is invited to agree to the draft text set out in the annex as part of the interim Submerged Assessment to be submitted to RESPONSE 25-2018 and HOD 55-2018 for approval.

Draft v0.006

Warfare Materials in the Baltic

HELCOM Submerged

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1. Introduction

1.1 The Warfare Materials Threat in the Baltic Sea

Contemporary society’s perception of the horrors of past wars is almost exclusively driven by historic sources such as film recordings, photographs and written documents that are presented in mass media. However, the legacy of these wars is ever-present all throughout European land and waters, including the Baltic Sea.

When an aerial bomb explodes, injuring and killing people after lying dormant underground for decades, or when white phosphorus from an incendiary bomb is washed ashore, burning the skin of vacationers searching the beach for amber, the wars of the past claim additional victims more than 70 years past their conclusion. The tragedy of such events is unspeakable and ultimately originates in the battles of the previous century and irresponsible disposal methods that were applied once the guns fell silent. The environmental damage caused by these munitions with are less obvious than the direct impact on humans, but they are nonetheless concerning. Still, our knowledge of the scale of munitions related contamination and ecosystem consequences remains incomplete.

Marine waters of every single abutter to the Baltic Sea contain warfare materials. Threats resulting from warfare materials may be direct and short-term. Among others, fishermen, divers, offshore wind farm constructors and beachgoers are affected and face the munitions hazard, merely while performing their daily work or while collecting objects in the surf. Every year people are severely injured after unintentionally getting in contact with warfare materials. Other threats are indirect and long-term such as the enrichment of carcinogenic toxic substances and their derivatives in the food web. The latter must be especially emphasized, due to the unknown scope of the effects and its potential effects on the whole ecosystem.

If these are not enough reasons to act, it should be understood, that detecting these munitions becomes increasingly difficult with time passing. Available detection technology depends on magnetism and therefore on the metal casing of the warfare materials such as bombs, sea mines and artillery shells. Corrosion continuously dissolves the metal and consequently eliminates the chance to find and remediate these sources of risk and contamination.

Initially driven by scientific institutes and organizations (both governmental and non-governmental) in the most affected countries, relevant measures were undertaken in each HELCOM member state to support expanding the knowledge base concerning munitions and their effects on humans and the marine environment. As a result of regional, national and international scientific research relevant knowledge increases and consequentially numerous recommendations, on how the munitions challenge can be addressed, are published. However, international coordination is necessary or inadvertent duplication of efforts, thereby wasting time and money, or failure to identify obvious synergies, will be unavoidable. An integral part of coordinating those efforts is a centralized ammunition cadastre including results of previously conducted and ongoing research, management and analysis options for historic data from archives as well as risk determination and monitoring tools. Coordinated efforts by all affected countries are going to provide decision makers with the ability to deal with all aspects of warfare materials in the offshore environment, covering the identification of munitions, monitoring of dump sites and ultimately the elimination of the threats in a systematic manner.

1.2 Introduction to HELCOM SUBMERGED

The HELCOM Expert Group on Environmental Risks of Hazardous Submerged Objects (SUBMERGED) works to compile and assess information about all kinds of hazardous objects and assess the associated risks.

1.3 Objective of the Report

1.4 Scope of the Report

1.4.1 Limitations

2. Warfare Materials – State of Knowledge

2.1 Historic Background

2.1.1 Historic Overview

The military occupation and reconstruction of Germany after WWII were negotiated in Potsdam in 1945 by Joseph Stalin, Leader of the Soviet Union, Harry Truman, President of the United States of America and Clement Attlee, Prime Minister of the United Kingdom. Even though there were numerous disagreements, the three leaders agreed on the disarmament and demilitarisation of Germany. In the resulting Potsdam agreement, the parties made terms that "The complete disarmament and demilitarization of Germany and the elimination or control of all German industry that could be used for military production" should be achieved and that "All arms, ammunition and implements of war and all specialized facilities for their production shall be held at the disposal of the Allies or destroyed. The maintenance and production of all aircraft and all arms, ammunition and implements of war shall be prevented.”

With Germany divided into four zones (American, British, French and Soviet), the parties were individually responsible for tending to any chemical weapons (CW), chemical warfare agents (CWA) and production facilities within their respective areas of oversight, either by adding them to their own arsenals or by destroying them by any means they found to be suitable. This was primarily done by submerging them in oceans and seas.

2.1.2 Modes of Entry

During the world wars the Baltic Sea was an area of intense battles. Do to the strategic importance of the Baltic innumerable combat actions of great variety took place, all of which caused entry of munitions into the marine environment. These range from naval battle between war ships, submarine torpedo attacks, air raids, to complex mine laying operations. In addition, test sites for marine weapons and exercise shooting ranges were established.

Immediately before and after the conclusion of WWII, the dumping of ammunition constituted an additional mode of entry of warfare materials into the Baltic. Dumping of munitions was carried out for a multitude of reasons. With the end of the war drawing closer, munitions were dumped by the German Armed Forces to remove hazardous munitions from areas subjected to imminent attacks, to prevent munitions from being seized by the advancing Allied troops and to demilitarize before the impending surrender. In the immediate post-war period, the Allies chose dumping at sea as modus operandi to conduct swift demilitarization and removal of warfare materials from German territory. The dumping activities that took place during the final stage of war and during the post-war period were conducted while being pressed for time, either by the attacking Allied forces or by agreed deadlines. In later years, dumping activities were considered an inexpensive and safe alternative to land-based disassembly and decontamination procedures.

In addition to the conventional ammunition, chemical ammunition and CWA were dumped as well. At the time it was believed that the vast amounts of water would neutralize the CWA. In contrast to the dumping operations in Skagerrak and Little Belt, where complete ships were sunk, the great majority of chemical munitions were dumped into the Baltic Sea containers.

2.2 Geographic Distribution

2.2.1 Dumping Sites

Germany

After the conclusion of WWII, the allied forces captured an enormous amount ammunitions and other warfare materials. Military organisations and scientist considered dumping the captured ammunition into the sea the best way for the disarmament of Germany immediately after the war. Nearly 1.6 million tons of ammunition of all kinds were dumped in the North Sea and the Baltic Sea in German waters. Some of these places are well known, others are only assumptions.

Two examples for sites, where a high amount of ammunition was dumped are Kolberger Heide and Pelzerhaken. For Kolberger Heide some reports indicate the presence of some 25,000 t of dumped ammunition, consisting mainly of mines, torpedoes and depth charges. The amount might be lower but is nonetheless concerning. In Pelzerhaken 50,000 t of mostly different types of bombs and artillery ammunition were dumped. Furthermore, a hull filled with blast furnace slag is located at the site. Accordingly, a combination of explosive and toxic substances is located on a small area.

Chemical Warfare Agents in the entire Baltic Sea

For CWA the areas of concern in the Baltic Sea are primarily the official dumpsites east of Bornholm and southeast of Gotland. In addition, vast amounts of chemical munitions were located in the Little Belt area as well as on the transport routes starting in Wolgast. Finally, there are unofficial sites of concern in the Gdansk Deep and the Slupsk Furrow. Types and amounts of dumped chemical munitions in the Baltic Sea vary by location. The Bornholm Basin, containing the largest part, holds over 90% of the chemical munitions dumped in the Baltic Sea.

The three different official dumping sites contain different types of CWA: the area of Little Belt contains approximately 5,000 tonnes of munitions (an estimated 750 tonnes of warfare agent) consisting primarily of Tabun, a nerve gas, while the Bornholm Basin and Gotland Deep primarily consist of mustard gas.

Although the available data on the total amount of dumped chemical munitions contains some gaps, it still provides a much more extensive and detailed picture than currently possible for conventional munitions. According to reliable information the HELCOM Report Chemical Munitions dumped in the Baltic Sea states, that around 40,000 t of chemical munitions have been dumped in the Baltic Sea (Born-holm Basin, Gotland Basin, Little Belt, Flensburg Fjord; Bay of Gdansk?). Of these around 5,000 t lie to the south of the Little Belt between Germany and Denmark, in direct geographic proximity to the German Exclusive Economic Zone (EEZ).

2.2.2 Confirmed Contaminated Areas

In WW II, a lot of marine areas were used as training areas. Nearly the complete coastline of Mecklenburg-Vorpommern was used either as training ground for antiaircraft defence by guns and coastal artillery, as Luftwaffe training area for surface bombing or as testing area for torpedo development. The other nations established such areas in a similar manner. The coastlines of Latvia, including the bay of Riga, Estonia and areas in Finland and Sweden were used as training areas. In all these areas exercise ammunition and dumped ammunition from the war time are present.

Nearly the entire Gulf of Finland was a war zone and was and still is a training area. In WWI the Russian Forces established the Forward-, Central- and Kronstadt positions with artillery batteries and minefields, In WWII a close meshed net of minefields was laid in the same area. Named Seeigel, Nashorn, Corbeta, Apolda or Juminda minefield, nearly 100,000 mines were laid in both wars. Complemented by countless bombs, artillery shells and depth charges, the result was an extensive battlefield.

Some exercise areas from WW II are still used as training areas by the abutting nations of the Baltic Sea today. In Germany the exercise areas Schönhagen and Putlos-Todendorf are used by German Navy, Air Force and Army.

2.2.3 Suspected Areas

Besides these known dumpsites and confirmed contaminated areas, it is also assumed that stray single items of munitions lie scattering along the former transport routes, e.g. from the German loading port of Wolgast to the designated dumpsites in the Bornholm Basin. During the dumping activities, warfare materials were scattered in the vicinity of the designated dumping areas and well away from them on the transport routes due to the practice of en route dumping. The wide distribution has its origins in the item-by-item basis, in which the majority of dumping activities in the Baltic Sea have been carried out. Consequently, warfare materials have been scattered in high density within or near the designated dumping areas - and in low density also outside of them.

Vague information about additional dumping activities could not be verified to date.

The ongoing relocation of objects makes the assignment of suspected areas a very challenging task.

2.2.4 Relocation of objects

Human and natural modes of relocation of warfare materials differ in magnitude and type of force. There are numerous anthropogenic ways of relocating warfare materials. Munitions may get caught in a fishing net and travel long distances before being released. Bottom trawling has by far the most significant impact on relocation due to a direct physical contact with high energy and the spatial dimension. Dredging has been reported to be a way of accidentally relocating munitions, even moving them ashore to holiday beaches. Due to its spatial limitation dredging plays a less significant role. The relocation of warfare materials may occur unintentionally, most likely involving objects resting outside the dumpsites marked on navigational charts and without the crew even being aware of it. Furthermore, some purposeful relocation of warfare materials happens in order to keep waterways free or to allow for the construction of offshore infrastructure.

Natural modes of relocation are mostly driven by currents and extreme weather events. Considering the comparably low strength of the currents, the common conclusion is that the horizontal relocation of large and heavy warfare materials is caused by anthropogenic activities. The force required to move containers or heavy munitions (e.g. large artillery shells or bombs weighing up to 200 kg) over noteworthy distances cannot be applied by natural processes. Only trawled fishing nets, dredgers or other large machinery moving along the seabed (e.g. for laying pipes or power lines) are recognized as being able to relocate large objects along the Baltic seafloor.

2.3 Properties of Warfare Materials

2.3.1 Types of Warfare Materials

Warfare material in the Baltic Sea can be divided into two major categories – conventional munition and chemical munitions and warfare agents. Conventional munitions can be further distinguished into explosive, non-explosive and incendiary. In addition, munition components that were either dumped or separated due to deterioration may be found. Finally, ship and plane wrecks are located on the Baltic seafloor. The following chapters describe these categories of warfare materials. They are subdivided into the multitude of types and nations they were deployed by.

2.3.1.1 Conventional explosive

2.3.1.1.1 Bombs

Bombs are weapons, that are transported by an aircraft, then dropped from the aircraft on a target and finally detonate when they reach this target. In 1849, the first trials with bombs from balloons were started by the Austrian Army. In 1911, an Italian pilot dropped bombs by hand from an aircraft to the enemy ground structures. Bombs are streamlined metal cylinder that are filled with an explosive charge and an ignition system. Different systems allow for the detonation of the bomb in a distance to the surface, on the surface or after impact. Professional construction and production started during WWI and the development of bombs is still ongoing.

Germany

The entirety of German airdropped bombs comprises of a cacophony of different types and sizes. The smallest bomb was the SD 0.5 with an explosive charge 0.031 kg. The biggest was the SA 4000 with a charge of 2700 kg Amatol 50/50. Most deployed were the SC/SD 50, SC/SD 250, SC/SD 500 SC/SD 1000 bombs. The number corresponds to the total weight of the respective bomb, 40% to 50% of which comprises the weight of the charge. Special constructions such as armour piercing bombs PC-class have a total weight that is comparable to the SC/SD bombs, but contain a smaller charge of 10% to 20%.

All of these bombs were used in the Gulf of Finland, the coasts of Estonia, Latvia and Lithuania, in Gdansk Bay and in the dumping areas along the German coastline.

Figure 1:Bombs

Soviet Union

The development of Russian Bombs progressed in similar fashion as in Germany or other nations. The types of bombs are similar in weight of up to 5000 kg. However, most produced was the 100 kg class. The form of the casing displays some minor differences to the constructions of other nations during wartime, but the effectiveness was nearly the same.

In addition to Soviet developments, the Allies supported the Soviet Union with warfare materials, including aircrafts, mines and other weapons. Accordingly, Soviet replications of this material can be found in the marine environment as well.

All kinds of the Russian Bombs were deployed throughout the majority of the Baltic Sea from the Gulf of Finland all the way along the coastline to Swinoujscie and Bornholm.

UK and USA

Bombs from UK and USA are comparable to German or Russian types in terms of construction and firing systems. Weights were given in pound (lbs) and not in kilogram. From 8 lbs to 12000 lbs were the produced standard sizes, but mostly used were bombs from 100 lbs to 1000 lbs.

The distribution area of UK or USA bombs is the western Baltic, the southern coastline of the central Baltic and the Gdansk bay. Allied bombers approached Germany via the border to Denmark and then changed the course to Kiel, Rostock, Stettin or other targets. The air defence attacked the bombers with artillery or fighter planes and in case of emergency bombers dropped the explosive cargo in the sea. The areas off the coast from Kiel, Lübeck, Rostock, Sassnitz, Usedom, Stettin, Gdansk and Kaliningrad are affected by a high density of submerged bombs.

2.3.1.1.2 Mines

The first trials with mines go back to the 18th century. Serious development started later and the first ever minefields were laid by Russian units in approach of Port Arthur in the Russio-Japanese War (1904-1905). From the beginning of WWI onwards, mines were essential weapons in naval warfare.

The estimated number of mines laid in the Baltic Sea varies between 100,000 and 150,000. Of these 35,000 to 50,000 mines were swept and have been removed. It is estimated that 35,000 mines remain in the Gulf of Finland. The most common mines deployed were contact mines. In general, two types of naval mines – moored and ground mines – exist and both types are still working.

Moored mines were invented prior to ground mines. Their case has a spherical shape, some with an additional belt connecting two hemispheres. Inside the mine casing the charge is stored in a separate container. The explosive charge in a moored mine weighs between 20 kg and 350 kg. The mines contain ignition systems that are based on different modes of contact ignition. Chemical Horns and switch-horns protruding out of the sphere give moored mine their characteristic look. Chemical horns contain a small glass phial with an electrolyte liquid. Resulting from a contact of a ship's hull with the horn, the glass breaks and the electrolyte closes an electrical circuit resulting in the ignition of the mine. Switch horn system contain a fully loaded battery in the mine case. As a consequence of outside physical contact to the horn the switch is operated and again a current circuit is closed, and the detonation initiated.

The mine case is filled with air, thereby acting as a floating body and providing buoyancy for the mine. It is moored to the sea floor by means of an anchor. A wire or a chain connecting the mine case to the anchor ensures, that the mine's position is maintained. Mines were located at a water depth between one and five meters when targeting surface ships and 100 m when targeting submarines. When the mooring was damaged by natural influences or cut by minesweeping gear, mooring mines ascended to the water surface. A secure system would open a hole in the casing, resulting in the mine being filled with water and sinking to the sea floor. Minesweepers also damaged the casing of mines by firing at them.

A contemporary challenge with legacy mines is the lack of knowledge regarding the constitution of the mines' ignition systems. For mines with a casing that is in good condition, it is possible to encounter fully functioning ignition systems.

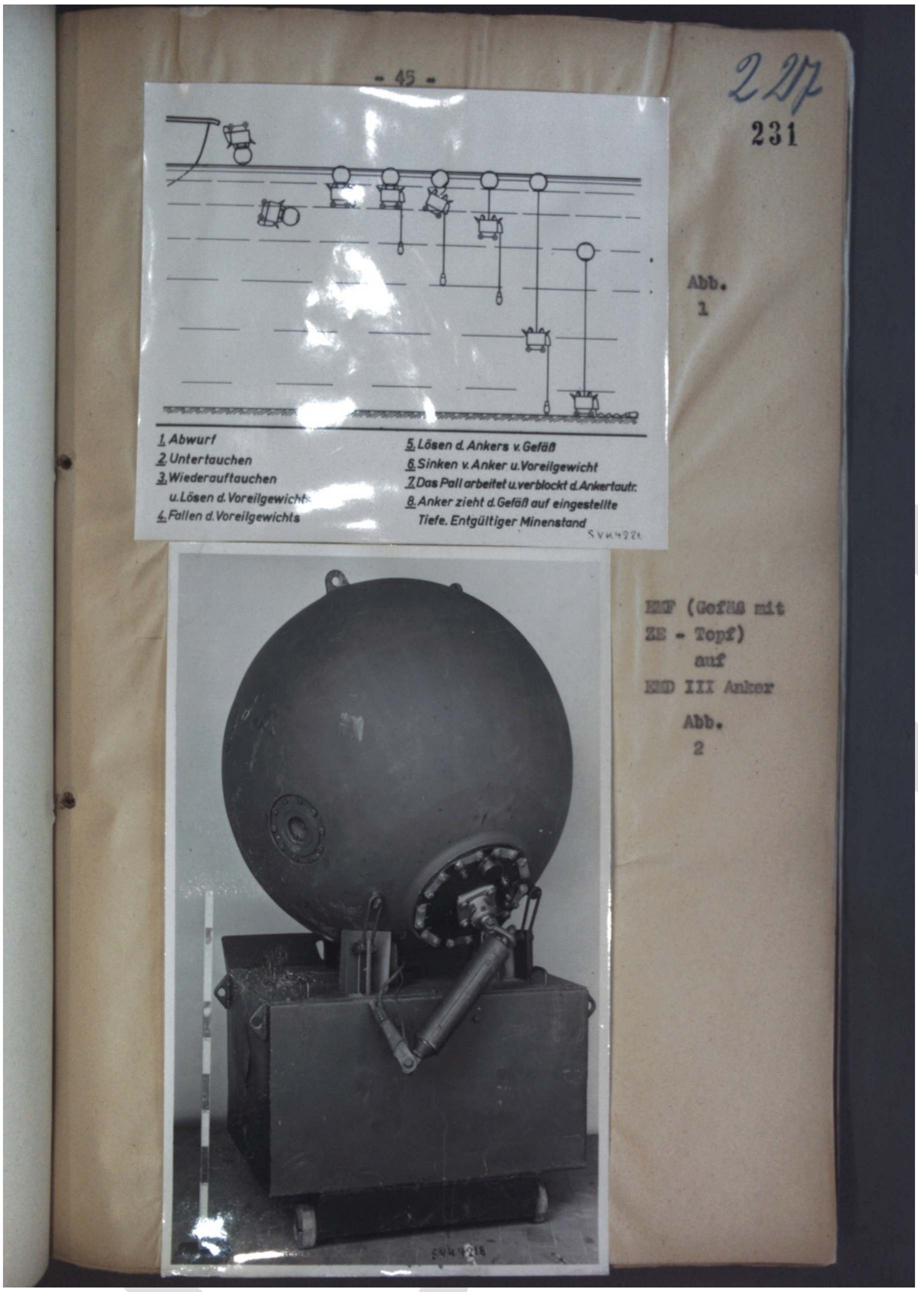


Figure 2: Deployment principle of moored mines

Ground mines were first developed towards the end of WWI, which also so a small number of ground mines being laid. In WWII ground mines were full functional.

The explosive charge of ground mines varies strongly between 45 kg and 880 kg. The ignition systems are magnetic, acoustic or pressure influenced. Combinations of two or all three variants were also developed. The magnetic field of a steel ship, the noise emanated by the engine and the marine propeller or the pressure change resulting from the displacement of water activated the ignition system. However, in order to function the ground mine requires a sufficiently charged battery.

Minesweeping against ground mines is intricate, as minesweeping systems need to be able to simulate the magnetic or acoustic fields of a real ship. The pressure displacement cannot be simulated by minesweeping systems.

Figure 3: Ground mine

<u>Germany</u>

In 1877, the first functioning moored mine form Germany, was commissioned. With an explosive charge of 40 kg and a simple contact-detonator, the mine served as a defensive mine to defend coastal waters. Later, in 1914, Germany deployed new, improved moored mines with chemical horns and a well-functioning depth setting system and charges of up to 220 kg. An additional development were UC mines, moored mines laid by submarines with a charge of 200 kg explosives. All mines were contact mines and the majority used chemical horns to trigger the ignition system. Between the wars, further effort towards the development of moored mines were made. The resulting EMC or EMF mines contained explosive charges of 300/350 kg and influence distance firing systems added the contact systems.

The development from ground mines started only during the 1920s. The development followed two paths: ground mines laid by surface ships or submarines and ground mines laid by aircraft. The LM (Luftmine) an BM (Bombenmine) are typical examples for air deployed mines and that could also function as a bomb. The explosive charge weighs between 290 kg and 720 kg. Ground mines laid by surface ships and submarines worked solely as mines and contain explosive charges of up to 880 kg.

Russia and Soviet Union

The development of mines in tsarist Russia and later in the Soviet Union was more advanced than in other countries. Part of the mines has similar characteristics as other mines, specifically the spherical cases and chemical horns. The mine-anchor has a greater weight and therefore providing superior stabilisation on the sea floor. Furthermore, the Russian Navy developed contact mines without chemical horns. The bottle with the electrolyte liquid was located inside the mine casing and a mechanical gear fixed a hammer. After physical contact by a ship, the mine case tilted, and the hammer broke the bottle. The electrolyte activated the detonation. This pendulum system was installed in a few numbers of mines in both wars.

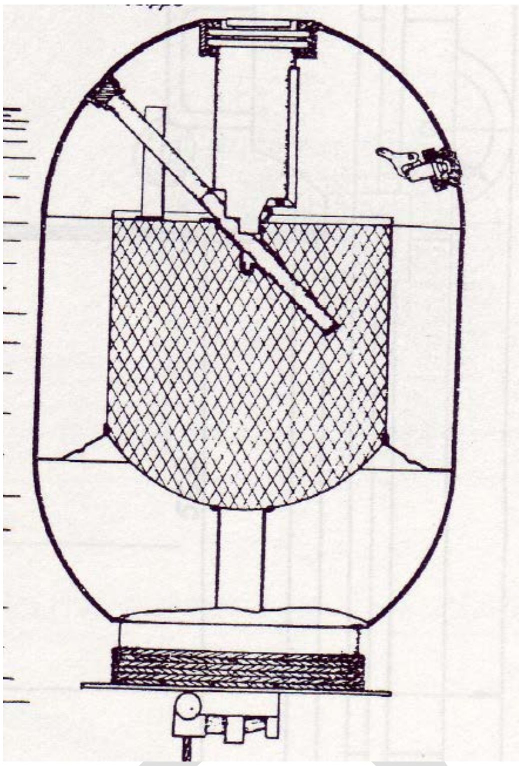


Figure 4: Mine with pendulum system

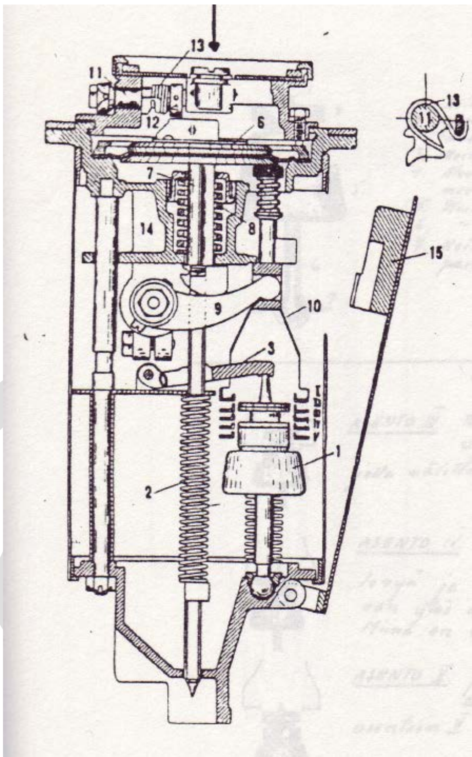


Figure 5: Pendulum System

The development of ground mines proceeded in similar fashion to that in Germany. Ground mines from the UK were provided to the Soviet Union after it entered the war, resulting in a mix of Russian and UK mines located in the Gulf of Finland.

Finland

Finland produced naval mines during WWII for the Merivoimat (i.e. the Finnish Navy). Most of them were replications of German, Russian and Swedish mines and own development efforts were very low.

Netherlands and France

After the war against France, the German Wehrmacht and Kriegsmarine captured some 100 mines from both navies. The fully functioning mines were added to the German mines in the Nashorn minefield, located between Helsinki and Tallinn from 1942 till 1944.

Sweden

The Kingdom Sweden was a neutral state during WWI and WWII. Sweden developed and deployed different types of mines with the purpose of defending and the securing Swedish harbours and national waters. The construction principle was the same as that of other countries.

UK

UK mines were used in WWII. In April 1940, the Royal Air Force started with so called “gardenings”. Areas that were mined first were the access to Kiel canal and the Kiel bight. Later the entrance to the harbours with dockyards and the exercise areas from the submarines were targeted. All mines were ground mines of the types MK I-IV, MK V, and MK VI-IX. In total 13543 mines were laid in the Baltic sea and the access route Kattegat.

A special variant are the “lent and leasing” ground mines from 1941. The UK sent some hundreds of mines to the Soviet Union which then used them in the Eastern Baltic.

2.3.1.1.3 Rockets

Germany

After WWI, Germany was not permitted to own airplanes, submarines and other highly developed warfare material. Civil research and development of rockets was a small, but effective branch. Werner von Braun drove the civil research, contacted with the research division of the German army and was eventually employed by it. The testing ground was established in Peenemunde/Usedom, which was initially out of reach of allied aircrafts. It was this test site, where the Luftwaffe developed and tested their rocket systems.

The V1 (or Fieseler Fi 103) was developed by the German Luftwaffe (i.e. the German air force) and built by Fieseler Werke, an aircraft construction company. The V1 was the first ever cruise missile, shaped similarly to a small aircraft, with a special jet propulsion and a warhead containing a 700 kg explosive charge. The V1 was in service by the Luftwaffe and used in WWII since June 1944 against Great Britain. In March 1945, the production was halted and the V1 that were ready for combat were collected in Schleswig Holstein. The last 200 V1 were dumped in the outer part of Flensburg Fjord on May 3, 1945 by German forces. Parts of them and nearly complete V1 can be found in dumping area.

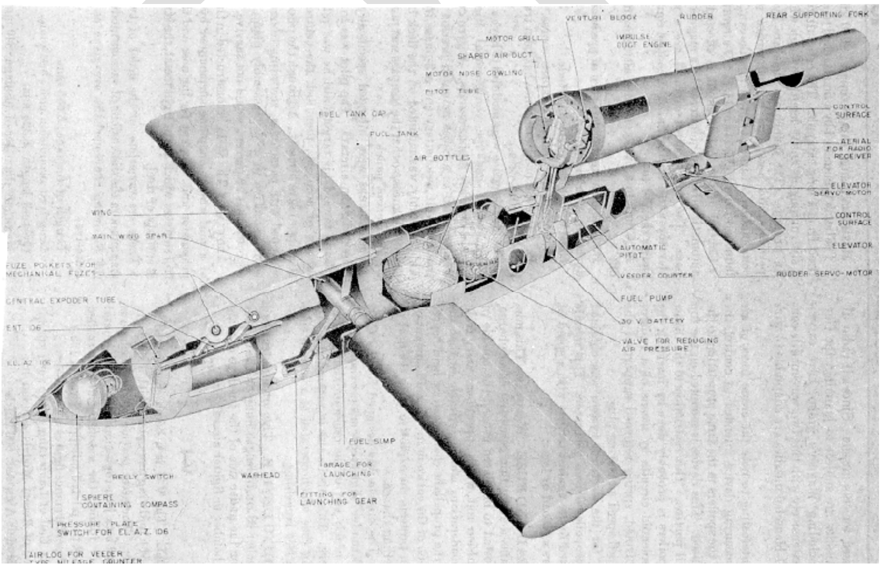


Figure 6: V1

The V2 (or Aggregat 4 – A4) was a rocket, that was produced and deployed, after a long time in development. With a firing range of around 330 km, the V2 was the first ballistic missile and nearly 3200 missiles were launched during WWII. It contained an explosive charge of 738 kg amatol.

Some additional types of rockets were produced and tested in smaller numbers. The types were Taifun, Wasserfall and Rheintochter were antiaircraft missiles, Rheinbote was developed for the surface to surface application.

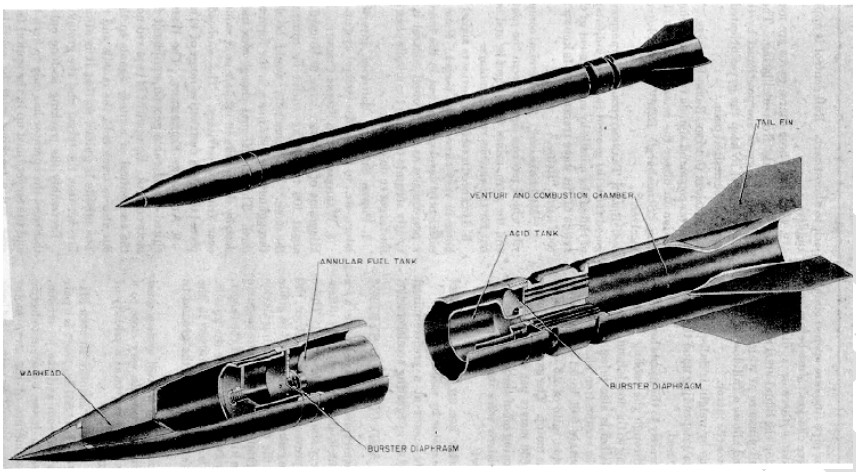


Figure 7: Wasserfall

Several rockets were developed for the Wehrmacht unit Nebelwerfertruppe and put in service. The rockets were unguided and contained a large explosive charge. They were utilized to support the firepower of artillery. After the war, rockets captured from the Nebelwerfertruppe were dumped in the known dumping areas.

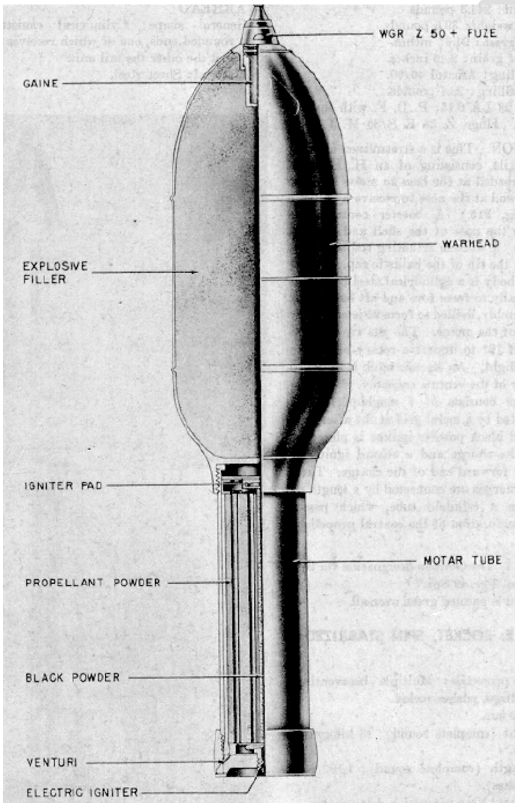


Figure 8: 28 cm Rocket launcher rocket

The Luftwaffe used some unguided rockets for air-to-surface attacks, as anti-tank weapons and in air-to-air combat. The diameter of these rockets was 5.5 cm to 21.0 cm and they were in service till 1944. The smaller units from the Kriegsmarine (War Navy) used a similar anti-aircraft rocket with the diameter of 8.6 cm.

Allied forces

Similar to the German forces, the allies used rockets in wartime. The unguided Russian missile Katyuscha is a well-known example. The coastline area all the way from Mecklenburg-Vorpommern to Estonia it is highly probable to encounter rockets, that were misfired in wartime or dumped afterwards.

2.3.1.1.4 Torpedoes

The torpedo is a self-propelled weapon, consisting of an explosive charge, a control system and a power source for the engine.

Germany

Already during WWI German torpedoes in different sizes existed. Their diameter ranged from 45 cm to 53,3 cm and in rare cases up to 60 cm on few battleships. The explosive charge had a weight of up to 300 kg and the installed ignition system was initiated by a contact fuse. The propulsion was achieved by releasing on air pressure resulting in the typical bubble trail that can be observed at the rear of a propelled torpedo. The firing range for these WWI torpedoes reached from 600 m to a few kilometres.

In WWII, two standard torpedoes were used by the Kriegsmarine. The torpedo G7a, that was again propelled by pressurized air, contained a charge of 280 kg to 300 kg. Its firing range reached from 6 km at a speed of 44 kn all the way up to 12 km at a speed of 30 kn. The other type was the G7e propelled by an electric engine and batteries. The torpedo contained the same charge as the G7a, but the G7e reached a firing range of 5 km to 7,5 km at a speed of 30 kn.

A great number of airdropped torpedoes were used by the Luftwaffe. The F5b torpedo had a diameter of 45 cm, propulsion by pressurized air and contained a warhead with a 200 kg charge. In the Baltic, two areas are affected by a concentration of F5b torpedoes. One is located close to Gdynia at former testing area “Hexengrund”, where lost testing F5b are submerged. The second area is located in the Gulf of Riga where a school was operated by the Luftwaffe in 1944 and numerous torpedoes were lost.

Russia and Soviet Union

The Russian torpedo development started with three torpedo calibres: 37,5 cm, 45 cm and 53,3 cm. All torpedoes were wet-heathers, meaning that they were propelled by injecting a liquid fuel into the pressure air chamber, further supported by the steam resulting from cooling the combustion chamber. They contained warheads ranging from 200 kg to 300 kg. In WWII the 45 cm version and a series of 53,3 cm torpedoes was used by the Soviet Union. The explosive warhead could by then carry an explosive charge of up to 400 kg.

2.3.1.1.5 Depth charges

The depth charge is a weapon developed for the combat against submarines. After beginning the submarine war in WWI, escort units required an antisubmarine weapon. The depth charge was the result. Explosives were filled in a metal case, a clockwork or a membrane (i.e. a pressure sensor) initiated the detonation after a certain amount of time had passed or the desired depth was reached. The detonation in the depth would result in damage or destruction of submarines.

Germany

The German depth charge carried an explosive charge between 60 kg and 130 kg. A special type was the depth charge with floating aid. The explosive charge weighed 60 kg and the floating aid reduced the speed of sinking.

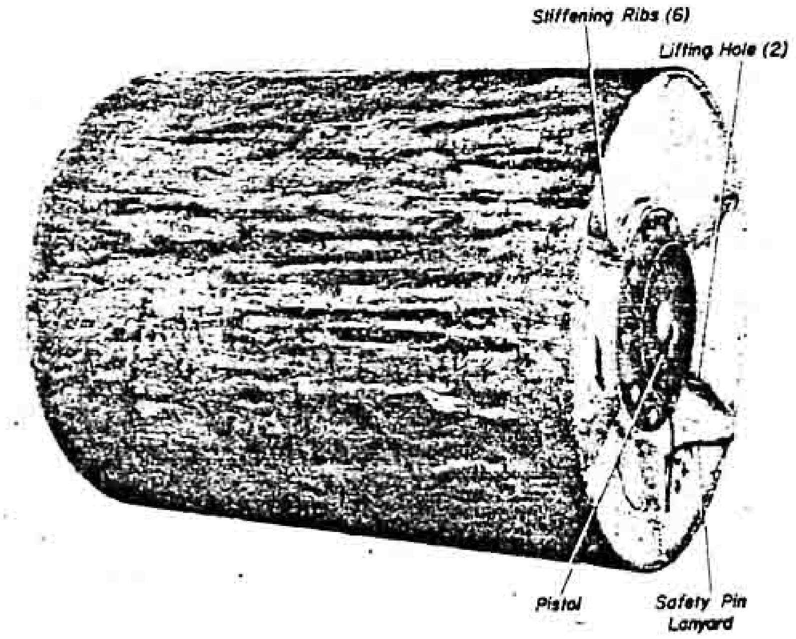


Figure 9: Depth charge

Russia and Soviet Union

The Russian and Soviet depth charges are similar to the German ones in terms of explosives utilized, shape and firing system installed.

2.3.1.1.6 Artillery shells

The history of artillery shells goes back to the middle ages. Originating from a hollow sphere filled with black powder and using a burning fuse, development over the centuries has resulted in the development of a high technology warfare material.

Naval forces used many kinds of artillery shells. The small calibres of 2 cm, 3,7 cm, 4 cm and 5,7 cm serve two purposes. The main application is as antiaircraft defence against aircrafts in low and medium altitude. As such the guns work in rapid fire. The second application is combat against surface targets over short and medium distances. These calibers were mostly deployed as main weapons of small vessels. The calibers of 7.5 cm, 10cm and 15 cm were installed as the main gun of vessels for use against surface targets. They were also applied for the second purpose as antiaircraft guns. The lager calibers from 15 cm up to 40,5 cm were used on battleships or as shore-based guns for coastal defense.

Usually naval artillery shells consisted of a combined grenade and cartridge up to a caliber of 12.7 cm. For bigger calibers grenade and cartridge were to separate components.

Figure 10: Artillery shells

The artillery shells used by ground and aerial forces were similar to those used by naval forces for antiaircraft purposes. Others such as field artillery and tank artillery consisted of separate grenades and cartridges. Some artillery shells had specific impacts. The variety encompasses exploding, hollowed, antitank, illumination, smoke and chemical agent shells. These differ terms of type of payload and the weight of the explosive charge in the grenade. The weight of the explosive charge in an antitank grenade for example is very small with just about 30% of the weight of a normal HE grenade.

2.3.1.2 Conventional non-explosive

2.3.1.3 Conventional incendiary

Incendiary munition is used for developed fire and not for damage by mighty explosion. The payload is a mixture of a small charge to open the grenade and scatter the brand mix. The mixture started the burning after the initiator, often white phosphorus get contact with air. The same principle has the incendiary bombs. The bombs were fulfilled with a light burning fluid and white phosphorus as initiator.

2.3.1.3.1 Incendiary bombs

Germany

Two types of incendiary bombs employed by the Luftwaffe existed. The smaller type, called Elektronbrandbombe, weighing 1 kg to 2.2 kg contained a small explosive charge of 0.008 kg to 0.015 kg and a thermite charge. The other type was filled with a mixture of oil and fuel and the initiator with white phosphorus. The biggest of this type was the C 500 bomb containing a mixed liquid charge of 157 kg.

For bombs releasing smoke for the purposes of camouflaging or target marking cases, that similar to those of the incendiary bombs, were used.

UK and USA

Incendiary bombs were of high priority both tactically and strategically. Similar to Germany, the Allies utilized small bombs containing thermite charges and bigger ones containing both a combustible liquid and a phosphorus charge. Up to 30% of 30 lbs incendiary MK III bomb with 1 lbs with phosphorus was misfired, meaning that it did not detonate upon reaching target.

2.3.1.4 Chemical

While conventional munitions contain explosives or incendiary agents and their effect is characterized accordingly by detonation or burning, chemical munitions are distinguished by a payload of chemical warfare agent. Their purpose is not the physical destruction of infrastructure, but rather directly or indirectly, a temporary or permanent incapacitation of humans due to the respective toxic effects of the compounds used. In addition, a strong psychological component exists, that is associated with the type of external injuries and the delay before their appearance (e.g. blisters on the skin). In contrast to the substances contained in conventional munitions, the hazards posed by chemical warfare agents for people and the environment appear obvious. Hence, researching this kind of munitions has received special attention in the past.

The majority of chemical warfare munitions dumped are aircraft bombs. More than half of the chemical munitions dumped (in tonnes) were aircraft bombs containing mustard gas. However, not all CWA were dumped as payload of munitions. A considerable amount was dumped in encasements and containers.

2.3.1.5 Munition components

2.3.1.6 Wrecks

2.3.2 Munition compounds

2.3.2.1 Explosives

2.3.2.1.1 Primary

2.3.2.1.2 Secondary

2.3.2.1.3 Payload

2.3.2.2 Combustibles

2.3.2.3 CWA

2.3.2.4 Other Materials

3. Warfare Materials –Effects and Risks

3.1 Known and potential effects

3.1.1 Detonation

3.1.2 Deterioration, Leaking and Contamination

CWA have been dumped already filled into diverse types of munitions, as well as in storage bulk containers such as barrels and drums. These containers differ with regard to wall thickness (e.g. thin-walled aircraft bombs and thick-walled artillery shells), type and quality of metal(s) used (e.g. resulting in contact corrosion where different metals are used) and other substances contained, resulting in different susceptibility to corrosion and therefore speed of decay and start of content release. In contrast to storage bulk containers, munitions contain different types of explosives. Unlike in conventional munitions, the main effect filling of chemical munitions is neither explosive nor incendiary mixture but a CWA (mixture). However, in order for a munition to have the effect intended by its users, the CWA payload has to be released from its metallic container when a certain event happens (e.g. countdown of a set time, shock of impact), for which chemicals with the ability to detonate (explosives) are used. The event of release is usually determined by the type of fuse employed in a munition. Fuses usually contain sensitive primary explosives (e.g. mercury(II) fulminate, lead(II) azide) which are used to set off a more stable and handling-safe secondary explosive (e.g. 1,3,5-Trinitrotoluene = TNT), sometimes via additional booster charges (e.g. containing the sensitive explosive picric acid or its salts). These chain reactions result in bursting of the container and release of the CWA payload contained. While munitions disposed of in organized demilitarization campaigns will likely have been dumped without fuses attached, the remaining explosive content still qualifies them as UXO.

Speed of corrosion and subsequent start of release of all chemical contents is strongly dependent on the local environment a given chemical warfare material container rests. In general, the presence of oxygen and engulfing currents will promote corrosion of a container, while burial in sediment and a low oxygen environment will preserve its original state. Even if the outer hull is still pristine, the chemical contents of a bulk container or, even more likely due to its more complex composition, of a munition may have changed with time.

To assess the threat to the marine environment, Makles and Śliwakowski (Makles and Śliwakowski, 1997) developed a model, from which it results that, depending on the type of ammunitions (containers), mustard gas will be escaping in the following way:

- barrels: start 23 years after dumping, complete loss of containment after 60 years;
- bombs: start 46 years after dumping, complete loss of containment after 120 years;
- artillery shells: start 69 years after dumping, complete loss of containment after 265 years.

Chemical warfare material objects are point sources of contamination. It is certain that with time, these objects will be broken down due to mechanical and chemical processes to become diffuse sources of local contamination, which will then be further distributed. Spreading may occur in solution or as particles bound to sediment particles fractions or in biota and may be accompanied by abiotic or bio-mediated chemical transformations of the released compounds. Thus, the disintegration of containers results in additional uncertainty with regard to the environmental fate of the formerly contained pollution load, taking into account that this is determined by the type of released compounds and the prevailing ambient conditions. As a result of further dissolving, dilution and the reaction of decomposition (dissipation), the possibility of the occurrence of high concentrations of munitions constituents in the seawater seems likely.

In general, anthropogenic activities capable of moving large objects like bombs or lumps of sulphur mustard will also be sufficient to achieve the spreading of contaminants in solution, as particles or bound to sediment particles. For instance, when bottom trawls are drawn over an area of contaminated seafloor, contaminated sediments may be resuspended, and the contamination may only spread locally.

Due to its chemical properties mustard gas is an agent that can remain stable on the seabed for decades after its metal encasings have corroded.

, the safety distance of a detonation – based on lethal or severe damage – is 4.3 km for divers, 2.8 km for harbour porpoises and 1.7 km for swimmers) (Koschinski and Kock, 2009)

A large number of papers focus on the underwater environmental impact of the pressure wave induced by the underwater explosion on the marine environment; and from personal communication with experts, another identified impact on marine flora and fauna is the post-explosion release of residues and combustion products.

3.1.2.1 Sea Water

Natural processes potentially causing the relocation and spreading of munitions and chemical warfare agents can be separated into those occurring on a permanent basis, frequently or only occasionally:

- Permanent – low force – diffusion from sources (e.g., resulting in the contamination of adjacent sediments, pore water and water in the immediate vicinity of the leaking chemical munitions).
- Frequently – low to medium force – horizontal currents of ordinary magnitude; disturbance by biota (bioturbation); and vertical transportation with gas generated by bio-degradation in the sediment and pore water from deeper layers, squeezed out due to the increasing weight of settling particles.
- Occasionally – stronger force – extraordinary events like the inflow of cold, salty and oxygenated water from the North Sea into deep basins of the Baltic Sea; strong currents caused by storm surges and ice (in more shallow or coastal waters).

The potential impact of these processes also depends on many local factors such as water depth; the depth of buried objects or point sources in the sediment; the composition of the upper layer of the seabed; and the temperature of the water.

Chemical warfare materials may be completely or partially buried in the sediment or they can be lying on the surface of the seafloor. Once the integrity of an encasement is breached, the contents of any object will spread due to the processes of advection and diffusion within the sediments and the water in the immediate vicinity of the point source. As described in Chapter XXXX, some chemical warfare agent associated compounds, when released into the environment, undergo a quick chemical transformation and detoxification; while other compounds might persist in the environment for long periods due to various factors (e.g., stability towards hydrolysis by the formation of self-contained lumps). While advection is related to the movement of ambient media in duration and velocity, molecular diffusion follows any relative difference of concentration, which is a very slow process. It needs to be noted, however, that muddy sediments dominate the former dumping areas in the Baltic Sea and their permeability is so small that the process of dispersion caused by advection currents – either induced by density or resulting from the pressure gradient – can be disregarded.

The water of the Baltic Sea is circulated, most notably forced by wind, but also by differences in water temperature and/or salinity and oxygenation levels which drives the movement of water. Strong forces may only occur in shallow waters and near to the shore. For instance, the maximum speed of currents in the Bornholm Basin has been measured at 20 cm/s at five meters above the seabed and up to 40 cm/s at forty meters over the seafloor (Garnaga & Stankevičius 2005, Missiaen et al. 2010). In addition to horizontal movements, the water also undergoes vertical mixing.

Findings made after the CHEMU Report (Paka & Spiridonov 2002) show that other noteworthy near-bottom turbulences occur in deeper waters as well. Two effects that might lead to the expulsion of contaminants from the seabed into the water column, and which could then be relocated by horizontal currents, have been described:

- Settling sediments - the increasing weight of the growing and settling of the topmost sediment layer results in the expulsion of water from deeper sediment layers that might carry (micro)particles/contaminants.
- Rising gas - generated by anaerobe biological degradation fermentation gases can form small bubbles rising upwards and causing micro-turbulences on the way, resulting in particles/contaminants being dragged along and ejected from the seabed.

Diverse species of biota inhabit the seabed or visit it regularly to feed on benthic organisms. When animals dig burrows into the seafloor or scour the sediment for prey, the layers of particles are mixed and released into the near-bottom water. Contaminated sediments will also most likely respond to these disturbances of the seafloor or accompanying near-bottom water movements. If the exposure to toxic chemicals is minor, the benthic organisms will not suffer from acute toxic effects; upon prolonged exposure, however, chronic effects are possible.

possible are not known. Recurring reports about artillery shells, parts of torpedoes or the engines of WWII cruise missiles (V1) found in the surf zone of beaches suggest that there is a natural process of transportation, but one which is not completely understood as yet. It is well understood that the force of waves rolling towards the shoreline increases with decreasing water depth. As a result, it can be concluded that objects will be relocated by waves either due to their low density in relation to seawater and / or if they are located in shallow water.

Munitions constituents can also be washed ashore. Incidents are recorded nearly every year of small pieces of the incendiary agent white phosphorus being found in the surf zones of the German island of Usedom and the Latvian beach south of Liepāja. Reports from other locations are rare. In the cases of Usedom and Liepāja, the toxic substance originates from the payload of incendiary bombs that were re-leased into the sea close to shallow water (cf. Chapter 3.2.5). As the encasements of incendiary munitions are rather thin, it is likely that some would have ruptured on impact; for those that did not, by today they are probably in an advanced state of corrosion and may even have broken up into pieces. In some munitions, solid white phosphorus was used while in others the incendiary substance was mixed with rubber-like sticky additives. The original substance which broke up into pieces upon impact or by waves has by now, most likely, been relocated naturally.

Any detonation, especially of old ammunition, releases toxic munitions constituents into the water due to incomplete combustion. This cannot be prevented using a bubble curtain (Pfeiffer 2009). Due to the lack of systematic studies, the amount of products of incomplete combustion cannot be quantified. Generally, in a high-order detonation the combustion of munitions constituents is more effective than in a low-order detonation or deflagration (Koschinski 2011).

3.1.2.2 Sea Floor and Sediment

3.1.2.3 Beaches

3.2 Risks to Humans

As discussed in Chapter XXX, chemical warfare agents like Sulphur mustard, Tabun and arsenic-containing substances were designed to trigger severe biological effects at very small doses. All of them are extremely toxic to humans. In many cases, the degradation products also show some degree of toxicity, while some compounds have the potential to be biomagnified.

This section mainly addresses potential exposures for the main users of the sea.

The threats of chemical munitions can be triggered in many ways: the munitions might function as intended and release the toxic contents by detonation after being improperly handled. A more likely scenario is direct or indirect contact (e.g. via vapours) to leaked liquid or solid chemical warfare agents that has become attached to an object (e.g. fish) or contaminated the sediment. In principle, the introduction of chemical warfare agents and their degradation products into the marine food web can result in contaminated seafood products for human consumption and thus pose a risk to seafood consumers, however, only one such case has been documented in the Baltic Sea region (cf. chapter 4.3.8). While hazardous chemicals like white phosphorus have been found on beaches, no cases of chemical warfare agents washed ashore have been reported since the HELCOM reporting system was established in 1994.

The occurrence of skin blisters is rather common, and the cause may also by other than exposure to chemical warfare agents, such as an infected injury or reaction to other hazardous substances. Tests to determine the toxic effects on fish have shown that mustard gas concentrations of 10 ppm have a lethal effect in eels but not in flounders (NATO/CCMS, 1995).

3.2.1 Fishermen

According to reported incidents, fishermen have been the main groups affected by munitions (both conventional and chemical) since dumping activities were concluded in the immediate post-WWII period (cf. Annex 7.2). The risk of coming into contact with the dangerous materials was seen to be highest when fishing inside or near to the former dumping areas. For this reason, these sites are marked on the official sea charts together with additional information on where fishing activities, anchoring and extracting seabed materials is not advisable. However, due to the former practice of en route dumping and the ensuing relocation of sea-dumped materials, there is also a risk when fishing is carried out outside the marked dumpsites.

In this context, the former practice of en route dumping is of special interest since these chemical warfare materials pose a considerable risk - one that is very difficult to assess due to the unknown locations outside the assigned dumping areas and because they were disposed of and scattered item-by-item. While the likelihood of trawling one of these objects is low, any such incident might have severe consequences due to the unexpected event and improper preparation.

3.2.2 Offshore construction and maintenance workers

The rapid growth of the offshore industry is accompanied by changes in human behavior and thus raises many new issues related to munitions (both conventional and chemical) dumped at sea. The documented experiences of the Nord Stream pipeline laying project between 2005 and 2011 could be a model for future project plans (Nord Stream AG 2010-2011). It substantiated the claim that chemical munitions are a threat to developments in areas outside the limits of ‘foul grounds’ and munitions dumpsites marked on navigational charts.

The use of the seabed for offshore activities such as resource extraction and construction is rapidly developing and increases the likelihood of encounters with dumped munitions. Offshore construction sites are a good example: where piles are rammed into the seabed there is a possibility to encounter munitions buried deep in the sediment. Available technologies to detect objects in terrestrial soil are insufficient, as are most of the present solutions for underwater detection.

The increased drilling of boreholes for geological surveys also increases the threat of coming into contact with toxic substances, which might occur if a chemical warfare object is punctured in the process or if examined sediment core samples include sediment which has been contaminated with chemical warfare agent mixtures.

The increasing amount of activity on the seafloor also increases the risk of coming into contact with conventional and chemical) munitions. Many temporary or permanent facilities will be deployed on the seafloor in the near future (e.g., Remotely Operated underwater Vehicles (ROV), maintenance stations, offshore wind farms, sea cables and pipelines). Operations on or in the sediment layer may damage the en-casements of the munitions that have not yet lost their integrity. Moreover, all of these installations are at direct risk from relocated military objects. Apart from the possible direct contact with hazardous objects, the operating personnel are also indirectly at risk from coming into contact with contaminated equipment such as tools, ROVs, diving suites and related gear.

Commercial, navy and emergency response sub-surface entrepreneurs and members of service crews related to underwater operations are seen to be exposed to an elevated probability of coming into contact with chemical and conventional munitions in the vicinity of dumpsites or scattered munitions, be it directly and indirectly, intentionally or unintentionally. Poor underwater visibility, the large variety in shapes of chemical warfare material containers and the degree of their corrosion and colonization by biota pose a challenge to even recognizing the potential danger. It should be stressed that some warfare agents will even penetrate the material of highly sophisticated gloves and diving suits and some substances (e.g., thickened Sulphur mustard mixtures), may stick firmly to the surface of objects they come into contact with.

The planning and preparation processes for sub-surface operations in suspected areas should include the implementation of standard operation procedures (SOP) for the unlikely event of an accidental contamination of workers or equipment. All personnel should be considered responsible for correctly carrying out such standard operation procedures. In the event of an encounter, the relevant national authorities must be informed and should thoroughly investigate and formally agree before the operation can be continued.

3.2.3 Nautical personnel

3.2.4 Harbour staff and workers

Investigations in local archives have confirmed that at almost all harbour facilities used for trafficking of (chemical) warfare materials, accidents with these hazardous goods have occurred (e.g., Flensburg, Wolgast). For the port of Flensburg, two accidents are recorded in relation to the turnover of warfare material in the immediate post-war period in 1945 (18 September, 1 October), as well as single recent incidents have been recorded in Denmark. While unloading rail cars with chemical munitions on behalf of the British Military Administration in Germany, workers were contaminated with sulphur mustard oozing from artillery shells damaged by fire or from barrels leaking due to unknown reason. The contaminated objects were sent off for emergency sea-dumping with immediate priority (cf. Chapter XXX).

It must also be assumed that the soil is contaminated in parts of the port which were formerly used for trafficking of (chemical) warfare materials.

As described for other sub-surface operations under Chapter XXX, information on the potential remains of former trafficking of (chemical) warfare material needs to be made available and taken into consideration by project managers or contractors to allow for responsible planning of future harbour developments. Since harbour basins often contain metallic objects of all kinds, and in high density, it can be difficult to identify potentially dangerous single objects. If historical information suggests that both, chemical and conventional warfare material has been trafficked in the area, then any activities in the basin should be undertaken with the utmost care.

Apart from objects that have been lying in harbours for decades, there is also risk of recently relocated materials being brought into the harbour by fishermen, possibly even without recognizing the hazards posed by some inconspicuous object in their nets. One such dangerous relocation case occurred on 4 April 2001 when the crew of a trawler outside the coast of Blekinge (Sweden) found a bomb containing Sulphur mustard in their fishing net and transported it to the harbour of Nogersund. The bomb was placed on the jetty and had to be dealt with immediately by the authorities. Another such dangerous relocation case occurred in Eckernförde (Germany) when a crew of a trawler caught a Mine with his fishing net and transported it to the harbour as well.

3.2.5 Recreational divers

Wrecks in general - also those from WWII - are of special interest to recreational divers. Most chemical munitions were dumped in the Baltic Sea at depths exceeding 80 m, mostly by item-by-item disposal and are located well away from the coastline and therefore are not easily accessible to recreational divers. The wrecks of the barges sunken in the area south of the Little Belt have been relocated and the materials recovered in the late 1950s (cf. Chapter 3.2.1). Of special concern, however, are the scattered single objects stemming from item-by-item disposal en route from the loading harbours to the formerly designated dumping areas (Flensburg ↔ south of Little Belt; Wolgast ↔ Gotland Deep; Wolgast ↔ Bornholm Deep) and in the area south of the Little Belt. Since these objects are not associated with a landmark of interest like a wreck, it is unlikely that these scattered chemical warfare materials will be found unintentionally in these shallower waters. However, novel, highly sophisticated and affordable equipment enables even non-professional divers to conduct ever deeper dives, which increases the likelihood of divers or their equipment encountering chemical warfare materials.

Therefore, easily accessible public information of the dangers associated with sea-dumped warfare materials (both chemical and conventional) should also be targeted to raise the awareness of this special risk group.

3.2.6 Beach visitors

Today, the likelihood of beach goers coming into direct contact with chemical warfare materials (not including the incendiary agent white phosphorus) is negligible. However, even though the number of encounters is very low, the consequences of such an encounter are disproportionately high due to the severe consequences for the affect individual (Figure 44). This requires that responsible authorities take appropriate action to prevent similar incidents from occurring in the future.

The high likelihood of confusing the incendiary agent white phosphorus with the collectible amber and its high occurrence at some sites (e.g., beaches of Usedom and off Liepāja) has been described in Chapter 3.2.5, Chapter 4.2.1.4 and Annex 7.1. It is seen as the special responsibility of local authorities governing the area of known hot spots to raise public awareness by clear and precise information for both beach goers and amber collectors. It should be clearly advised that before storage, amber should be collected in fire-proof metal containers and allowed to dry and heat up to 30°C when any white phosphorus mistakenly collected will ignite. If white phosphorus is found, the area must be cordoned off and the authorities contacted. Further information for collectors who have been in immediate contact with white phosphorus should be included in the emergency operation procedures. Medical personnel in the wider area of concern also need to be aware of the special toxic dangers posed by white phosphorus and not just the obvious, severe burn injuries.

There seemed although a growing risk of encountering conventional munitions or arts of it on beaches. Beach maintenance employees and life guards should receive training and public awareness increased through clear warning signs. The implementation of munitions related topics within the voluntary eco-label “Blue Flag” (www.blueflag.org) might introduce a top-down strategy for further improvements in how to deal with the legacy of war in present times.

Another way to raise the attention of beach visitors is the hand out of “awareness brochures”. This has taken place for example at the beach area of Heidkate (Germany) in 2015 after several findings of explosives. Children had collected the explosive compounds and played with.

3.2.7 Seafood consumers

As pointed out in Chapter 4.3.1, the highest likelihood of getting into direct contact with chemical warfare materials in the Baltic Sea is through commercial fishing. Consequently, there is also a risk for any fish netted with the warfare materials to be contaminated (e.g., with small lumps of potentially sticky sulphur mustard, Figure 45). When this occurs, the authorities must be alerted, the fishing gear decontaminated and the whole catch destroyed. As mentioned in Chapter 3.3, some constituents of chemical warfare materials have the potential to bio magnify within the food web. This has been assessed to potentially affect commercially valuable and primarily sediment-active top-predators such as Baltic cod. This species is also of particular concern since the Bornholm dumpsite is located in one of its main breeding areas and offers rich fishing grounds (Niiranen et al. 2008).

No parent chemical warfare agent-associated compounds have been detected in Baltic Sea fish. Based on models results, Sanderson et al. (2009) assessed the maximum recommended monthly amount of fish servings3 stemming from the primary dumpsites/no-fishing zones in the Bornholm dumpsite to be zero to one. This assessment was based on extreme worst-case assumptions, taking into account the load of arsenic-containing chemical warfare agents dumped in the area, but not specifically addressing all potential transformation or break-down products. Their study concluded that there was a need for further empirical research, especially regarding the speciation of arsenicals in fish and their carcinogenesis as well as the effects of human exposure to sulphur mustard via seafood.

Studies aiming specifically at the Geno toxicological effects of chemical warfare agents are still on-going within the CHEMSEA project (cf. Chapter 2.3.2.2.2 and Torre et al. 2013). The possibility of sulphur mustard poisoning occurring via seafood consumption is supported by newspaper reports stemming from the late 1940s (June 1948, April 1949). It was reported that some Danish and German seafood consumers had become ill after eating fish caught in the area of the Bornholm dumpsite – cod roe later assessed by medical staff was found to contain Sulphur mustard (HELCOM 2011a). However, the exposure occurred due to mechanical mixture of warfare compounds with fish roe that was consumed. Bottom-dwelling fish chronically exposed to chemical warfare agents due to their on habitat association in vivo in a dumpsite in the Mediterranean Sea off Bari, Italy, have been shown to carry obvious signs of biomarker responses; however, no chemical warfare agents were found in the fish flesh and thus any skin diseases, parasite infestation and general low health could be connected to overall environmental stress factors. Further research in this field was recommended by the authors (Torre et al. 2013). While no specific analysis for the presence of warfare material constituents is conducted, it is unlikely that seafood showing such signs would go unnoticed in the sorting stage and reach the customer.

3.2.8 Munitions clearance service providers

3.3 Risk to Infrastructure

3.3.1 Pipelines and cables

3.3.2 Offshore buildings and platforms

3.3.3 Harbours

3.4 Risks to Marine Life

Fish, marine mammals and sea birds may come into direct contact with the chemical warfare materials themselves (e.g., leaking munitions or lumps of chemical warfare agent) or via contaminated food. Such direct contact with active chemical warfare agents will likely result in chronic toxic effects which manifest as behavioural changes and superficial injuries (e.g., skin blisters and lesions from contact with sulphur mustard). The development of blisters on the skin or mucous membranes of fish and marine birds and mammals are seen as the most obvious effects of contamination with blistering agents.

While similar studies for the Baltic Sea are still on-going (e.g., within the CHEMSEA project, cf. Chapter 2.3.2.2.2), research into the exposure of benthic fish species permanently inhabiting a dumpsite in the Mediterranean Sea off Bari, and sometimes even within the chemical munitions themselves, highlight the difficulties associated with conducting habitat-scale analyses or ecosystem assessments. Even though the observed state of illness – mainly skin lesions and blisters – suggest that it might be attributed to the blistering agents present at the site, from a scientific perspective the authors could only attribute those observations to be 'reasonably' ascribable to compounds leaking from the corroded munitions (Torre et al. 2013, cf. Chapter 4.3.8).

Russian studies on the toxicity of low concentrations of mustard gas (0.33 mg/L and 0.0033 mg/L) presumed to be present in bottom water over dumped munitions, showed toxic effects in zooplankton (Daphnia Magna) but no acute toxicity to gastropods and fish. Similar concentrations found over Adamsite and chloroacetophenone munitions produced no acute toxicity in the above-mentioned organisms (Gorlov et al. 1993). Other studies on the subject have also been carried out based on measured or modelled effect-concentrations (Sanderson et al. 2007), showing that environmental risks towards the fish community in the Bornholm Basin from dumped chemical warfare materials cannot be ruled out by decreased solubility of chemical warfare agents.

A severe injury and subsequent infection may cause the death of a wild animal. Determining whether an infected injury is related to exposure to an active chemical warfare agent is difficult at best and identifying the actual cause of death of a decomposing body found on a beach is even harder. As post mortem examinations of marine animals typically point to more than one possible cause of death, statistics on cause of death tend to be unspecific.

Like humans, larger and long-lived forms of marine life suffer from chronic diseases like cancer or genetic defects after having been in exposed to low doses of toxins over a long period. The impacts of long-term effects are often gradual and may remain hidden inside a population. They are difficult to diagnose and correlate to a single cause-and-effect relationship. While the influence of chemical warfare agents cannot be completely excluded, natural and other anthropogenic pressures must also be considered. However, a definite and unequivocal identification of a single impact is often difficult to obtain.

Preliminary results obtained from the studies carried out within the CHEMSEA project (Lehtonen et al. 2013), showed lower fitness, an elevated prevalence of bacterial skin ulcers and gill parasites (Loma sp.), a higher degree of head kidney pathology and a higher degree of genotoxic effects in fish caught in the dumpsite area compared to the control areas. Moreover, comparatively low lysosomal membrane stability, possibly attributed to arsenic stress, was found both in fish and in the blue mussel caging study in the 'hot spot' area of the Bornholm deep compared to the reference area. Compounds stemming from chemical warfare agents have been detected in sediment and pore water samples in the wider area of the Bornholm dumpsite (cf. Chapter 3.3, Missiaen et al. 2010, Sanderson et al. 2010, Nord Stream AG 2011c).

Conservative model-based assessments on the environmental risks to fish from the sea-dumped chemical warfare materials in the Bornholm Basin dumpsite conclude that primarily sediment-active species (e.g., sole) and omnivorous fish (e.g., cod) would potentially be at risk, whereas primarily pelagic species (e.g.,

Salmonidae) would be at a lower risk, assuming an extreme worst case scenario. Clark-type warfare agents, especially triphenylarsine as a constituent of arsine oil (technical-grade Clark I), were identified along with Adamsite and Sulphur mustard as compounds of special concern (cf. Annex 7.1) (Sanderson et al. 2008). Based on various sources, Sanderson et al. (2008) derived Toxic Units which represent the combined risk toxicity of chemical warfare agent compounds to the fish present in the primary and secondary dumpsites in the Bornholm Deep. The risk to the fish community under the more realistic Scenario B is marginal (TU< 0.2) in a 4-metre thick layer and 58 km down current (Figure 46) (Sanderson et al. 2008, and references therein). These figures, however, represent modelled concentrations and may be underestimated in individual cases.

Preliminary studies aiming at an environmental risk assessment for the western part of the Lithuanian EEZ, which overlaps with the dumpsite in the Gotland Basin, found that the studied parameters - arsenic contamination, arsenic-tolerant bacteria and zooplankton - did not produce well-defined responses concerning potential risks. More specifically, the need for the determination of individual chemical warfare agent signature compounds at dumpsites was identified as a prerequisite for the evaluation of potential environmental risks (Garnaga & Stankevičius 2005).

A different environmental marker for the presence of sea-dumped warfare materials was found by researchers detecting and isolating bacterial strains tolerant to the hydrolysis products of Sulphur mustard (Medvedeva et al. 2009). The isolated strains were cultivated in the laboratory and were shown to be capable of biodegrading thiodiglycol-type compounds stemming from abiotic hydrolysis of Sulphur mustard, even at low temperatures (5 °C). Bacteria with these capabilities were found to occur to an unusual degree in the centre of the designated dumping area off Bornholm and in the dumpsite of the Gotland Basin. These bacteria represented up to 85% of all heterotrophic bacteria found in samples of near-bottom water less than 1 m above the seabed taken at these sites (up to 85% at the Bornholm site; up to 20% at the Gotland site). While these bacteria usually only comprised 0.5% of all bacteria counted in the samples, it needs to be noted that the occurrence at a reference site outside the known dumpsites was determined to be 3% of all heterotrophs. In samples with a higher percentage of these tolerant bacteria, a diminished diversity of bacterial species was also found. The enriched presence of the specialized bacteria was attributed to the occurrence of Sulphur mustard-type warfare materials known to have been dumped in the areas under investigation. The authors of the study concluded that the results suggest the potential for the self-purification of contaminated water and sediments by natural populations of microorganisms (Medvedeva et al. 2009). The fact, that none of these specialized bacteria were found in water samples taken above 1 m over the seabed, underlines the limited stability of Sulphur mustard when it is dissolved in seawater. It needs to be noted, however, that these findings do not diminish the hazards posed by persisting solidified Sulphur mustard-type materials formed by aging processes or stemming from special tactical mixtures. It is unclear to which extent microbial degradation can assist in breaking down and detoxifying the chemically self-contained lumps of Sulphur mustard encased in a protective layer of polymerized material and consisting of undiluted and most likely also active agent (cf. Annex 7.1).

While no major impacts on the marine environment of the Baltic Sea as a whole are currently discernible, there is also no clear picture on the potential and future long-term effects of sea-dumped warfare materials. The legacy from the past is still resting on the bottom of the sea and is inextricably linked to the fish of today, and it may be that its effects will only be discernible on the consumer of tomorrow.

3.4.1 Marine Mammals

Old sea-dumped ammunition poses a threat to marine mammals and the environment. For cetaceans, the conventional ammunition removal by blasting is a particular hazard. High sound pressure and explosion-related shock waves can lead to severe injury and hearing impairment in marine mammals at considerable distance from detonation sites.

Underwater detonations represent the loudest anthropogenic point sources of noise in the Baltic Sea and have the potential for serious injury in marine vertebrates and invertebrates at ranges of several kilometres (Koschinski 2011, von Benda-Beckmann et al. 2015). By conversion of solid energetic compounds into a much larger volume of gaseous reaction products, any explosion results in a shock wave characterised by a tremendously steep wave front and a very high pressure maximum called “overpressure”.

The shock wave (created by the extremely high detonation velocity and expansion of the resulting gas bubble) propagates into the surrounding water. Animals can be seriously injured at considerable range by the overpressure of the blast wave which is transmitted directly through body tissues. Both the extremely short signal rise time and the high peak pressure in the pressure signature of a detonation are related to the extent of injury to marine vertebrates. Based on experimental data from terrestrial mammals held under water it is assumed that smaller animals are more vulnerable than larger ones (Yelverton et al., 1973; Young, 1991). This raises serious concerns about shock wave effects on fish larvae (cf. Stein 2010, xxx) which would directly threaten protected fish species and also have economic consequences with respect to commercial fish species.

The shock wave results in primary blast injury (PBI) originating from the compression of tissues or organs by the incoming wave front. High-amplitude pressure pulses may cause differential tissue displacement disrupting cells and tissues of different density such as muscle and fat. Especially at the interface with gas-filled cavities capable of compression, molecules are displaced resulting in damage to these tissues. Tissues at these interfaces are torn or shredded by instantaneous compression of the gas. Hence, massive damage can occur in the lungs, intestines, sinuses, and ear cavities (Landsberg 2000). The compression of the thorax by the shock wave causes rapid increase in blood pressure resulting in the rupture of blood vessels and haemorrhages (e. g., in the brain and ears) (Ketten 1995) or rupture of lung alveoli leading to air embolism inhibiting oxygen supply e. g., to the brain (Landsberg 2000). Cavitation occurring shortly after the shock wave can cause gas embolism by nitrogen bubble formation in supersaturated tissues and fluids in diving animals (Lewis 1996).

Retrieving dead fish at the detonation site is a well-known result of shock waves. Information on fatalities of marine mammals or birds is mostly anecdotal because post-detonation surveys are rarely made. For example, in 2011 a time-delayed underwater detonation with a charge weight of 4 kg resulted in the death of three or possibly four long-beaked common dolphins as a group of dolphins entered the 640 m safety zone 5 min prior to the detonation (Danil & St. Leger 2011). In 1982 more than 2,000 dead harbour porpoises washed ashore as a result of an explosion at a gas drilling platform in the Azov Sea (Notarbartolo Di Sciara 2002). In 2006, 70 western grebes were killed by six demolition charges of 4.5 to 13.2 kg at 15 m water depth. Necropsied birds showed clear signs of PBI. The birds may have been attracted to fish killed or debilitated by explosions (Danil & St. Leger 2011).

Besides direct mortality by the shock wave, sublethal effects such as hearing impairment (acoustic trauma) or increased mortality by predation can also contribute to overall effects. Depending on the charge weight and location of the detonation, harbour porpoises can suffer acoustic trauma at distances much over 10 km from the blast (von Benda-Beckmann et al. 2015). Such sublethal auditory effects can affect the fitness of affected various marine animals in which hearing is vital for their ecology and behaviour. This is especially important for small cetaceans such as the harbour porpoise that rely on this sense for their orientation and prey acquisition (Richardson et al. 1995). Any sublethal impact leading to reduced survival, growth, or reproduction can impact populations (National Research Council 2005). A negative population impact has been predicted by a modelling study on the basis of spatiotemporal harbour porpoise density data from the Netherlands and available information on number, location and size of all explosive ordnance disposal operations (n=88) by the Dutch Navy during a 1-year period (von Benda-Beckmann et al. 2015).

Depending on the severity of the blast, acoustic trauma can either be temporary or permanent. A temporary threshold shift (a well-known effect from loud rock music concerts) is caused by physiologic exhaustion of sensory cells. A permanent threshold shift can be the result of a loss of hair cell bodies and subsequent degeneration of hearing nerves or severe injuries including damage in middle and inner ear caused by blast overpressure: rupture of ear drum, fracture of ossicular chain, or damage to the basilar membrane (Ketten 1995, Landsberg 2000). Seals are assumed to be more sensitive to acoustic trauma than cetaceans (Southall et al. 2007). Furthermore, harbour porpoises may be more sensitive than other species of cetaceans (Lucke et al. 2009).

3.4.2 Other Marine Life

Shock waves can also be deleterious for marine invertebrates which do not have gas-filled cavities in their bodies. Even small explosives have the potential to kill all kinds of invertebrates (Jennings & Pollunin 1996). However, the knowledge about the mechanisms involved and possible size of effect zones for invertebrates is scarce. Some information can be extrapolated from known effects of other high-intensity acoustic pulses (e. g., seismic impulses which usually contain less energy compared to underwater explosions of UXO) on different life stages of marine invertebrates.

Such as in fish larvae (see above), malformations and delay in development of marine invertebrate larvae have been observed – such as in scallop larvae exposed to playbacks of seismic impulses (Aguilar de Soto et al. 2013). Due to the similarity of high-intensity acoustic pulses, susceptibility to such types of injuries can be inferred from this information. In sensitive areas such as recruitment areas these effects can have serious implications for the viability of a population. In the case of commercial species this also would have economic implications.

Circumstantial evidence suggests that high-intensity acoustic pulses such as produced during seismic surveys represent a threat to squid[1] species (Guerra et al. 2011). Shock wave injury in squid resulting from underwater explosions is thus also likely. Due to the lack of systematic studies, other studies must be used as a substitute to explain the possible mechanisms in the event of injury caused by shock waves. Increased mortality in cephalopods and ultrastructural damage in their hair cells associated with impulsive noise from seismic surveys was observed off the Spanish coast. Controlled sound exposure experiments in the laboratory revealed that exposure to low-frequency sounds can result in permanent and substantial alterations of the sensory hair cells of the statocysts, which are the structures responsible for the animals' sense

[1] The relevance for the Baltic Sea is given due to the regular occurrence of several cephalopod species in the Kattegat, Belt Sea and Western Baltic Sea. There are records of Allotheutis subulata and Eledone cirrhosa in the Kattegat and Loligo spec. (forbesi/vulgaris), Sepietta oweniata, Sepiola atlantica also in the Western Baltic Sea (depending on salt water inflow) – Uwe Piatkowski, pers. comm..

of balance and position massive acoustic trauma. Such injury is not compatible with life (André et al. 2011, Solé et al. 2011).

4. Warfare Materials – Methods for Management

4.1 Assessment methodologies

4.1.1 Historic Reconstruction

All military decisions and circumstances were documented in different forms. Archives, especially military archives, store these documents. The research and check of relevant documents are of high importance and information generated during historic reconstruction are relevant for the determination of subsequent measures. Due to the large amount of preserved orders, reports, diaries, logs and other documents, the military archives are extremely valuable. The challenge however, is to be able to find and identify the documents, relevant for the research scope.

<u>Sources</u>

The military archives of Germany and the UK both contain a mighty stock of documents. German military documents were captured during the final weeks of WW II or after the war. They were brought to the UK and to the USA for evaluation. Most were later given back to Germany and they are now stored in the military archive in Freiburg. Around 51 km of files are currently stored, and the archive is a source of paramount importance for historic reconstruction. The database is however not complete: Some gaps in the special operations section indicate, that some files were lost.

The UK National Archive in Kew holds a significantly larger volume of documents than the German archive. The quality of the files is similar to that in Germany and is complemented with files of the naval historical branch and the UK Royal Air Force (RAF). It is therefore possible, to generate an excellent historical reconstruction.

<u>Methodologies</u>

The first step of historical reconstruction is scoping and the definition of research boundaries regarding a specific operation, a geographic area or a timeframe. Furthermore, the affected components are determined. The archival research is initiated with basic data and information. In the research process war logs of the involved units, diaries of members of staff and of higher commanders are investigated. All influencing factors, such as weather conditions, enemy threat, navigation and morale of the crew and commanding officers constitute important inputs. Collecting complementary information from the opposing warring faction leads from a one-sided representation to the development of a complete picture.

A very good example are the minelaying activities conducted by the RAF in February 1944. The account was completed by examining the war log of the air defence area Kiel, the war logs of the minesweepers in the Kiel bight, the mining maps produced by the RAF and the summery report of the Royal Navy.

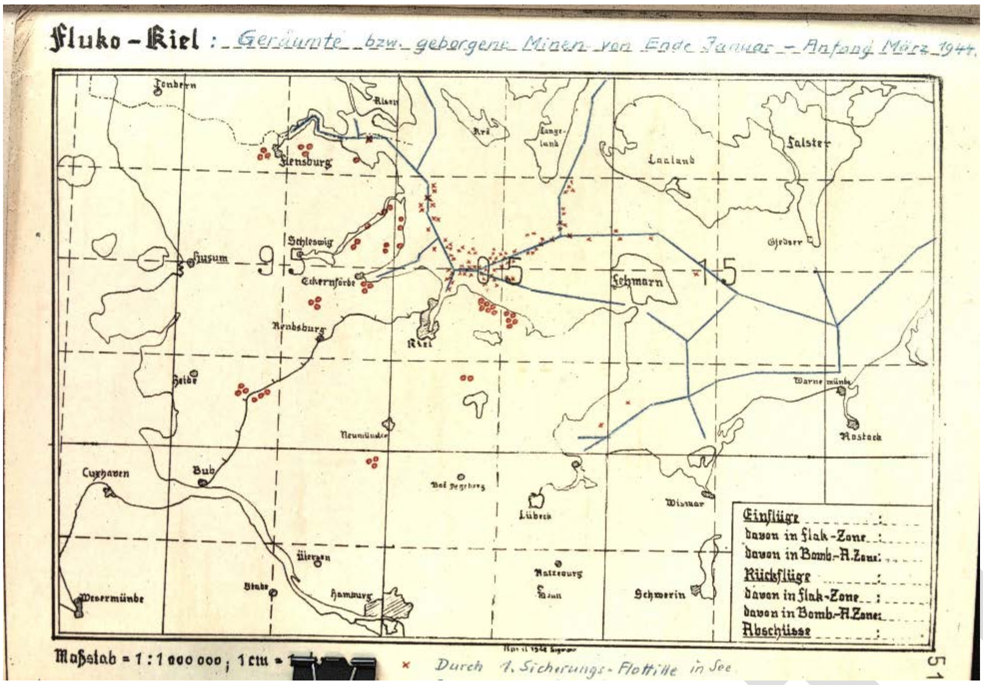


Figure 11: Mine clearance of RAF mines

4.1.2 Hazard Assessment

4.1.3 Risk Assessment

Introduction to risk assessment

The term “risk” has been described as being related to future events, their probability of occurrence and their resulting consequences. Since the future is unknown, uncertainty is associated with these events and their consequences. In order to assess the methodological potential of risk assessment, comparative studies of literature were evaluated, and essential aspects of different approaches were identified.

It is important to consider at which point in a decision-making process the risk assessment shall be applied. It can serve as a rough prioritization tool of various problem areas, or as a concrete planning tool for specific challenges. At the higher level, it is capable of supporting strategic decision-making, while at the lower level it can assess specific damages or other consequences and identify options to prevent them (MacDonald et al. 2004).

Risk assessment methods can be fundamentally differentiated between two opposing techniques for reality reconstruction; deterministic and probabilistic approaches. Deterministic approaches are based on clearly defined, rigid causal chains that, with the help of technical discretion and safety factors, are suitable for meeting technical standards and legal requirements. By contrast, probabilistic approaches evaluate relationships based on statistical or estimated probabilities as variable causalities in order to arrive with an interpretable risk assessment (Risktec Solutions w.y.; Thompson & Frazier 2014). Since the definitions of the approaches in the evaluated comparative studies are partly ambiguous and sometimes even contradictory, only the lowest common denominator is presented here.

In order to assess risks, it is necessary to decide on the handling of scenarios. Probabilistic approaches allow the consideration of all possible levels of intensity of a risk event. Deterministic approaches, on the other hand, lend themselves to the investigation of a single known scenario. This allows, for example, for the assessment of a worst-case scenario.

However, in reality, not the best known or the most extreme, but the most probable scenario is the one to be expected (Kirchsteiger 1999). In summary, when assessing risk, an exclusive singular approach (one scenario - deterministic) and a fully inclusive approach (all scenarios - probabilistic) exist. The decision whether to consider only a single or all scenarios affects the investigation of the sources of danger. A deterministic approach always considers only those sources of danger that lead to the occurrence of the assumed scenario, while probabilistic approaches are suitable for investigating multiple sources of danger (and their interactions). The probability of severe consequences plays a pivotal role in the selection of the appropriate approach. If a large number of acceptable scenarios are to be expected to have severe consequences, a deterministic approach is suitable. However, if the expected consequences are only severe in a few cases, a probabilistic approach is appropriate (McGuire 2001). An exception are components with extremely high safety relevance (such as in a nuclear power plant), if their failure is associated with catastrophic consequences (Kirchsteiger 1999).

Furthermore, the interpretation of the results depends on how reality is reconstructed. The results of a deterministic view are to be treated as certainties under the established conditions. The results of a probabilistic analysis, however, have to be assessed by applying statistical measures of dispersion (Kirchsteiger 1999). This allows probabilistic methods to take into account uncertainties, whereas for deterministic methods all assumptions have to be considered definitive (Sander & Öberg 2006). The quality of these assumptions and consequentially the quality of the results of the risk assessment is therefore directly dependent on the level of knowledge of the person or group of people making the assumption (Kirchsteiger 1999). So, if a deterministic view applies to anything other than a worst-case scenario, detailed knowledge of the case must be available (McGuire 2001). The tendency to investigate worst case scenarios with this approach is thus a compensation for lacking knowledge (Lonati et al. 2007).

Risk assessments are feasible for different spatial dimensions. This depends, inter alia, on the position in the decision-making process as described above, since at a higher level e.g. geographical areas can be prioritized (MacDonald et al. 2004). In addition, both the increasing complexity of the data situation and the increase in the vulnerability of the risk recipients commonly lead to a reduction of the spatial area that is to be considered (Sterr et al. 2000).

In addition, temporal aspects are to be considered. Risk assessments can be predictive or reactive (Essl et al. 2011). The applicability of approaches to risk events, that took place in the past, depends on several factors. The speed of materialization of consequences may vary (acute or chronic). Effects may occur latently or cumulatively. Finally, it is essential to regard how resilient the affected risk recipients are, as higher resilience hints at their ability to regenerate (Burger & Gochfeld 1992).

<u>Example: Requirements for the risk assessment of an accidental detonation</u>

A method is required to assess the risk during the concrete interaction between ROV, UXO and marine environment. The method must allow for the assessment of the risk during the deployment of different ROV technologies on different types of UXO in a variable environment. The assessment is not a matter of a rough prioritization, but the analysis of a specific technical challenge.

In order to define the requirements for the risk assessment in dealing with remaining UXO, it has to be determined which risk event should be at the centre of the study. A risk event is defined as the moment in which a dangerous activity produces a concrete danger. The risk event stands between the sources of danger that can lead to its realization and the consequences that can arise from it (Hamzah 2012). The use of ROV in dealing with explosive ordnance on the sea bed is considered a dangerous activity. One possible risk event is the accidental detonation of the weapon.

The choice between a deterministic and a probabilistic approach has to be carried out separately for sources of danger and consequences. The sources of danger that can lead to the risk event are diverse due to the variety of existing UXO. Various ignition systems, various types of explosive charges and the uneven physical and chemical state of the UXO and their contents (Böttcher et al. 2011) produce a wide range of scenarios, so that a probabilistic approach should be used. This is also supported by the fact that the use of ROVs is executed, in order to avoid the use of divers. The consequences of a detonation cannot be considered catastrophic. Therefore, a dilligent inspection of the probabilities of occurrence should be performed for the sources of danger. However, for considering the consequences at least partially a deterministic approach lends itself to the study. Since total loss of the ROV is expected in the event of a detonation, a deterministic worst-case scenario is appropriate. However, for other risk recipients, such as the marine mammal population, the consequences depend on their presence in the area of detonation (von Benda-Beckmann et al. 2015), suggesting a probabilistic approach.

The spatial extent of the consideration of the sources of danger should be limited due to their diversity. In addition, the vulnerability of affected risk recipients in the face of a detonation is high. However, for the assessment of the consequences, the spatial extent must not be smaller than the acoustic and physical field of action of the detonation. This therefore represents the lower boundary of investigation of the consequences.

The temporal nature of the approach that is to be developed for the risk assessment of a detonation must be predictive. A reactive view is not effective, because of the extremely short temporal extent of the risk event and the acute occurrence of its consequences. Resilience again depends on the risk recipient. While the ROV has a resilience close to 0, the population of marine mammals is more resilient. Their regeneration period should therefore be included in the risk assessment.

4.2 Quality Management in Offshore UXO Treatment

If activities surrounding the detection and clearance of UXO are executed erroneously, managed poorly or even overall omitted, UXO threaten the lives of construction workers (see 3.2.2), the construction schedule, marine fauna (see 3.4.1) and the public image of the involved parties. However, preserving comprehensively high quality during UXO operations in the offshore environment has turned out to be a challenging endeavour for a number of reasons:

- Entry barriers into the attractive market are low, leading to cost pressure.
- Legal areas are manifold and oftentimes not rigorously regulated.
- No guideline for the validation for the appropriateness of applied technologies or for the qualification of appointed personnel exists.

The successive increase in knowledge about the potential impacts of the UXO legacy has led to an urge to address the problem on a strategic level. In order to tackle the challenges raised above, a quality guideline for the handling of UXO in the offshore environment was developed. This quality guideline is posed to serve as a normative reference framework for all stakeholders involved in UXO operations.

The global ocean economy is predicted to double in size by 2030, as compared to 2010, thereby reaching an annual gross value added of USD 3 trillion and providing more than 40 million full time equivalents to the global labour market (OECD 2016). The ocean economy's potential to outperform the expected growth of the overall global economy is reflected in the Blue Growth Strategy laid out by the European Commission. In this strategy the economic potential for the extended economic use of the oceans was recognized and focus was placed on five blue growth sectors. Two of these sectors (ocean energy and seabed resources) require the capacity to safely access large areas of the sea floor (European Commission 2017). For sea floor utilization of this magnitude, UXO constitute a hazard and an obstacle (Bundesministerium für Wirtschaft und Energie 2017). Due to the variety of modes of entry of UXO into the sea over a timeframe of more than 140 years, ensuring a site is UXO free is not possible in many areas, without conducting an appropriate investigation in prior. In order to utilize the economic potential of the ocean energy and seabed resources sectors, an increase in UXO detection and removal action in affected areas will become necessary. Accordingly, the market for these services can be expected to grow and attract new actors.

UXO detection and removal operations are conducted in various judicial areas, some of which are only weakly regulated. While national law regulates work that is performed in the territorial waters in a fashion similar to that on land, the adjacent EEZ is subject to less regulation, as determined in the United Nations Convention of the Law of the Sea (Office of Legal Affairs - United Nations 2006). In case of Germany labour law is valid in the EEZ (Bundesministeriums der Justiz und für Verbraucherschutz 1996) explosives law however, is not (Bundesministeriums der Justiz und für Verbraucherschutz 2002). This weak regulatory regime becomes especially noteworthy, when, as in Germany, the majority of offshore wind parks are erected in the EEZ (Federal Ministry for Economic Affairs and Energy (BMWi) 2015). Such a situation results in lower barriers to entry the market, again with the consequence of attracting new actors.

Some aspects of offshore UXO removal are covered in normative or other guiding documents. The most extensive document is an account on assessing and managing UXO risk, published by British construction industry and research association CIRIA. This document focuses on the assessment of probabilities and consequences of UXO encounter and proposes management options (Cooper & Cooke 2015). A technical work aid (Arbeitshilfen Kampfmittelräumung) available in German, details the procedure of UXO treatment onshore. Notwithstanding its limited transferability to the offshore domain, it has been utilized during offshore UXO campaigns in the past (Arbeitskreis Arbeitshilfen Kampfmittelräumung (AK AH KMR) 2014). Other aspects, relevant to offshore UXO clearance, such as diving, hydrographic measurements and piloting of remotely operated underwater vehicles (ROV) have been addressed in other documents published by certification organizations and international governmental organisations (e.g. Hagenah & Klaproth 2016; International Hydrographic Organization 2005; International Marine Contractors Association) 2016) However, no document exists, that comprehensively suggests technical and managerial best practices relevant for the entire procedure of offshore UXO treatment.

In conclusion, new actors enter a market in which only few publications covering best practises or quality standards are available. This constellation ultimately threatens to deteriorate operational quality in the industry. In order to address the challenges laid out above strategically, a quality guideline for the treatment of offshore UXO was developed (Frey & Holländer 2018).

The basic principle that accompanied the development of the quality guideline for the treatment of offshore UXO was the quality definition given in EN ISO 9000:2015, according to which quality is the "degree to which a set of inherent characteristics (…) of an object (…) fulfils requirements” (DIN-Normenausschuss Qualitätsmanagement, Statistik und Zertifizierungsgrundlagen (NQSZ) 2015). Accordingly, it had to be understood what the following terms mean in connection with offshore UXO treatment:

- the object
- the characteristics
- the requirements

Figure 12 displays, that the object was characterized as both the entirety of services and practices, relevant for offshore UXO treatment in a given area, and as the actors, that are involved in their assignment, execution and supervision. The characteristics of the object were defined to be the technologies deployed and the personnel, employed by said actors during the sequence of services, as well as the surrounding natural conditions, relevant to the execution of these services. Finally, it was determined that requirements had to be defined for personnel, documentation, communication and reporting. Requirements regarding deployed technologies and surrounding natural conditions had to be specified by numerical threshold values where possible.

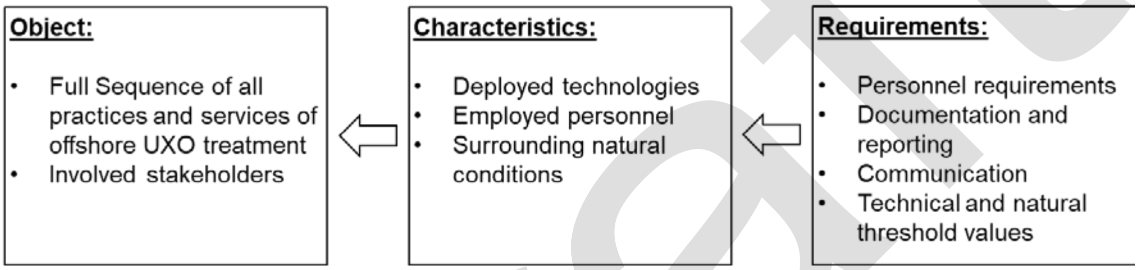


Figure 12: Aspects of the EN ISO 9000:2015 quality definition applied to offshore UXO treatment

Key to the composition of a widely recognized quality guideline was the involvement of all stakeholders relevant to the procedure of offshore UXO treatment, that would be affected by the finished quality guideline once it would be published. However, initially a comparative analysis of twelve existing process flow charts, that cover UXO clearance onshore or offshore was executed, with the aim of identifying their weak points, generalizations and redundancies. This assessment served as a basis for the generation of a new holistic four-phase-scheme akin to the basic structure of existing technical work aids. For each of the four phases, the relevant processes and involved actors (i.e. the object) were identified.

In a second step, two workshops with focus on different phases of the four-phase-scheme were organized. Next to the initiation of stakeholder involvement, the workshops’ goal was the identification of technologies, personnel and natural conditions (i.e. characteristics), relevant to the clearance of UXO in the offshore environment, as well as the description of detailed requirements for the individual processes. The workshops were attended by domain experts representing employers of the offshore construction industry, survey specialists, UXO service providers, consulting companies working in the field, scientists and public authorities. Additional expert interviews further aided the process.

A primary version of the quality guideline was drafted, which was made available to the domain experts for commenting and annotation. The comments were incorporated in the quality guideline, thereby turning it into a secondary version. In the final step, expert groups met to discuss the last remaining details that had still remained ambiguous during the workshops and could not be clarified during the annotation period. Two expert groups were held in April 2018, two more are due in October/November 2018. The quality guideline is going to be published in the first quarter of 2019. Initial publication is going to take place in German language.

Resulting is a quality guideline, that covers the entire procedure of offshore UXO treatment. The detailed description of the four phases is preceded by a general section. Here, a glossary defines central terms of the guideline and relevant legal and normative works, that are applicable to aspects covered in the guideline, are listed. Next, the relevant actors and their competence requirements are presented. The section is concluded by an introduction of pertinent personnel resources.

The following chapters describe one of the identified phases each. The four-phase-scheme is divided as follows:

- Phase I: Pre-Investigation
- Phase II: Technical Investigation
- Phase III: Investigation of Suspected Sites
- Phase IV: Clearance and Disposal

Each phase is further subdivided into processes. The subdivision is depicted in four individual flowcharts. A total of 30 processes covered in the quality guideline are spread over the phases (five processes for Phase I, eight processes for Phase II, nine processes for Phase III and again eight processes for Phase IV). For each of these processes a general description is provided, that focuses on the function of those actors, that are involved in that particular process. The majority of these descriptions is supported by a sequence of operation diagram. The process descriptions are complemented by a delineation of alternative scenarios and, where necessary, by specifications of suitable technologies and their way of application. For processes that require reporting or documentation, respective necessary content items are listed.

The final section is a reference section for quality drivers of deployed technologies or natural conditions. The section provides definitions for these quality drivers and, where possible, sets threshold values, that serve as termination criteria for specific processes. Furthermore, it describes the interrelationships that connect the quality drivers.

The quality guideline is not legally binding and receives its authority through the rigorous process of its generation and the strong involvement of a wide variety of affected stakeholders. The legally non-binding nature provides certain advantages such as higher flexibility, that may facilitate compromise during the generation of the document. The barriers to reaching consensus may be lower for the creation of a non-binding document and its responsiveness to the advancement of technologies and to the expansion of knowledge is higher (Taylor et al 2014). Nonetheless, the quality guideline's value for the stakeholders depends on the joint application of the document and its acceptance as a work of reference for future projects. It can be leveraged by different actors to commend its utilization. Public authorities may mention and recommend the guideline in collateral clauses and use it as reference for the approval of work concepts. Employers on the other hand may couple the award criteria of their tender offers to the adherence to the document. Lastly, the service providers for UXO detection or clearance may regard it as a basis for the establishment or strengthening of their internal quality management systems.

4.3 Modes of Detection

For the detection of warfare materials, numerous technologies are considered state of the art. These can be grouped into geophysical, hydrographic and chemical sensing methods.

4.3.1 Geophysical Methods

Geophysical survey methods are commonly utilized for the detection of munition both at land and sea. They include seismic, radioactivity and gravity measurements. However, for the detection of munitions magnetic and electromagnetic methods are applied.

4.3.1.1 Magnetic methods

Magnetic methods belong to the group of potential field methods, meaning that they make use of a potential field, in this case the earth's magnetic field. Like for any other magnetic field, the strength of the earth's magnetic field at any given location on earth can be measured with a magnetometer. The practical application lies in the possibility to measure anomalies in the otherwise rather constant earth magnetic field. These anomalies are caused by magnetic objects and can be measured if close enough to the magnetometer. (Butler et al. 1998)

Therefore, magnetometers are only applicable for munitions that contain an amount of ferrous materials, that is high enough to be measured by a magnetometer (Schwartz & Brandenburg 2009).

4.3.1.2 Electromagnetic methods

Electromagnetic methods send out an electromagnetic field. In case this electromagnetic field meets an object that is made of a conductive material (e.g. metal) currents are induced. These currents cause the creation of a secondary field, which is then measured by the electromagnetic sensor. This allows for the detection of items, such as munition, that cause the creation of such a secondary field. (AK AH KMR 2014)

4.3.2 Hydrographic Methods

Ammunition detection using high frequency multibeam snippet backscatter information: The present study reports the evaluation of snippet backscatter information gathered with a high-frequency multibeam echosounder system (200–400 kHz) due to their usability to detect ammunition of different sizes in shallow coastal waters. Besides the feasibility of the snippet backscatter data, it was focused on the attainable horizontal accuracy in comparison to side-scan sonar and autonomous underwater vehicle (AUV) surveys. The data was collected in shallow coastal waters of up to 18 m water depth (Baltic Sea) close to an ammunition dumping site characterized by an almost flat seafloor covered with sand and silt sediments. The analysis of the multibeam compared to sidescan data indicates the snippet backscatter to be a promising prospective method for ammunition detection and being able to improve horizontal position accuracy of up to 0.08 m.

4.3.3 Chemical Analysis Methods

Chemical contamination from underwater conventional munitions includes both organic energetic compounds (or, “munitions compounds”, MC) and metals such as lead and mercury. The most prevalent munition compounds are TNT (2,4,6-trinitrotoluene) and RDX (1,3,5-Trinitro-1,3,5-triazinane) (US EPA, 2012). Of these, TNT in particular is susceptible to a number of degradation and transformation reactions that form various amino derivatives. Both TNT and RDX exhibit toxicity to biological receptors, as do the amino derivatives of TNT (Lotufo et al., 2017).

Underwater munitions, particularly those on the seafloor since the 20th Century World Wars, are impacted by corrosion (Silva and Chock, 2016; Sanderson and Fauser, 2015), which exposes the solid explosive material inside. Some estimates suggest that corrosion will lead to maximum chemical release rates in the early twenty first century from submerged munitions in the Baltic Sea (Granbom, 1994; Malyshev, 1996; Glasby, 1997). Once exposed, the solid explosive material dissolves and is released into seawater. The few field studies that have been able to collect water samples very close to or within breached munitions show that dissolved munition compound concentrations approach solubility limits (mg L−1 range; e.g., Porter et al., 2011). Dissolved MCs are rapidly diluted away from the munition point source, and analytical detection limits have largely prevented quantification at levels present in the free water column or sediments (typically at the ng L−1 or µg kg−1 level).

Once released from solid explosives, TNT is readily transformed to various derivatives by microbial and abiotic processes, but probably does not undergo aromatic ring cleavage and mineralization. In contrast, RDX is more susceptible to complete degradation. The different degradation products can provide useful information about dominant reaction pathways, and they may prove an important tool for evaluating environmental fate and transport controls. However, there are many possible degradation products (summarized in Beck et al., 2018), which presents an enormous analytical challenge. To date, our poor understanding of MC release, transport, and fate in the marine environment is especially a result of insufficient analytical capability.

One major accomplishment within the UDEMM project was the development of an ultra-high sensitivity method for detection and quantification of MC in seawater, sediments, and biological tissue (Gledhill et al., submitted). Samples collected during field campaigns over the period 2015-2017 were measured using this new method and observed widespread MC contamination throughout the western Baltic Sea. Dissolved MC concentrations were generally low (10’s of ng L-1) in the water column but were a thousand to a million times higher close to exposed munition surfaces (up to mg L-1 levels less than 10 cm away). Degradation product compounds were also detected in the water column, but at lower concentrations. A very small fraction of MCs in the water column were detected on suspended particles (few percent of levels in the dissolved phase), but MCs and especially their degradation products were widely detected in sediment samples from the western Baltic region. The amino-dinitrotoluenes and diamino-nitrotoluenes were usually present in sediments at higher concentrations than the parent TNT compound, indicating that MC do undergo transformation in marine systems. However, it remains unclear how long the degradation products persist in sediment, and the degree to which they exhibit toxicity to marine ecosystems.

4.4 Modes of Clearance

4.4.1 High Order Detonation

The high order detonation is a common disposal practice for conventional munition items that cannot be transported and are therefore destroyed under water or on sandbanks that are dry during low tide. A typical high-order explosion under water is characterized by high detonation velocity (5,000 to 10,000 m/s) resulting in an extremely short rise time of the pulse and consequent shock waves that can proliferate for many kilometres (Koschinski and Kock 2009).

High order detonation always follows a handling step. Usually the placement of a donor charge or projectile-firing. Munition that is not safe to transport but safe to handle under water, may be moved under water, in order to remove munition from the vicinity of infrastructure or to perform a consolidated detonation of several munition items. If it is not safe to handle ammunition under water, currently the only option is to blow it in place (BIP).

A major advantage of BIP is that no handling or transportation of the UXO is required. Due to the small number of exposed workers, BIP is considered a very safe disposal method (Schwartz and Brandenburg 2009).

A variant of the high order detonation is the consolidated detonation, although mentioned in literature only very rarely. The process is described by Schwartz and Brandenburg (2009) as follows: “A consolidated shot is similar to BIP except numerous munitions are disposed at the same time and at the same location.” Several reasons from cost-reduction to local seafloor condition (detonation only possible in one place), or safety reasons (risk of unintended sympathetic detonations) might lead to the decision to conduct one consolidated, rather than several individual explosions. The effects of a consolidated explosion are qualitatively comparable to the ones of single explosions, but the overall impact of the explosion is higher when all targets are detonated simultaneously.

In contrast to the comparatively low risk to personnel, the adverse impacts on marine life (particularly mammals), as well as the risk of damage of offshore infrastructure and underwater objects in the vicinity, is assessed to be very high (GICHD 2016). Böttcher et al. (2011) conclude that due to the potentially enormous impacts on the marine environment, high order detonation should be considered only as an ultima ratio with an urgent need for the development of effective mitigation measures. Underwater Single Explosion is the most commonly used method, and valued as the cheapest, most flexible method.

4.4.2 Low Order Detonation

Low Order Detonation can be defined as “any explosive yield less than a full high-order” (Pedersen et al. 2002), typically characterized as a rapid burn (deflagration) of the explosive material. Depending on various parameters, the reduction of explosive yield can vary from 25% to up to 90% as compared to a high order detonation. Donor charges are designed in a way that the shells of the UXO are penetrated and the necessary energy for deflagration is provided, however, without an explosive shock sufficient for full explosion (Pedersen et al., 2002). Böttcher et al. (2011) report on a variation of this method, the underwater incineration of explosives using thermite. Tests showed insufficient reliability of the method with an incineration fail rate of 90%.

Overall the literature is critical about the proliferation of deflagration residues which may have high toxic potential. The fact that the deflagration of explosives yields different residues from a full high order detonation has been discussed critically also by other authors. First, not always a full deflagration is achieved, tests that Pedersen et al. (2002) have conducted showed unburnt TNT residues in some cases. Koschinski (2011) even speaks of 25% unburnt material on average. Also, the waste stream of the reacted substances was stated to be a disadvantage of the method. While Böttcher et al. (2011) do not see potential in the approach, Schwartz and Brandenburg (2009) consider low order detonations a less commonly used, yet feasible option that has shown positive results in tests. Koschinski (2011), Koschinski and Kock, and Detloff et al. (2009) do not regard it as a suitable method for its increased risk of contamination.

4.4.3 Mitigation

In the light of the increasing need to remove offshore UXO, and provided the negative consequences of detonation practices, it is necessary to develop environmentally friendly and cost efficient approaches for their treatment or ways to mitigate the consequences of existing techniques. If a detonation cannot be avoided, the surrounding marine life should be considered and a combination of technical and organizational mitigation measures, appropriate to protect the environment, should be implemented.

The EU Marine Strategy Framework Directive (MSFD) covers inter alia the introduction of energy into marine waters, including shock waves and underwater noise. The aim of the MSFD is that by 2020 noise levels “do not adversely affect the marine environment” in the EU can only be achieved by an extensive reduction of underwater detonations. If detonations cannot be avoided completely, due to the imminent danger to humans posed by certain munitions, combinations of suitable mitigation measures should be applied in order to minimise adverse environmental effects. In light of the critical situation of the harbour porpoise population of the Baltic Proper with less than 500 animals remaining (ASCOBANS 2016a), authorities should make every effort to ensure that the unexploded ordnance is recovered in line with requirements under the EC Habitats Directive and without subjecting marine life to the threat of being seriously harmed. The resolution no. 8 "Addressing the Threats from Underwater Munitions" (ASCOBANS 2016b) encourages Parties to support research, investigating the risk to marine animals and habitats from underwater munitions, and recommends, that international guidelines should be developed, including those advising on safe recovery methods and mitigation measures, when no alternatives to detonations are feasible.

Table xxx lists a number of mitigation methods for reducing the impact of underwater detonations on marine animals. A performance monitoring is required for all mitigation measures in order to document the fulfilment of legal conservation requirements and to further improve mitigation. The following chapters scrutinize some of these mitigation options in sequence of their application.

Table 1: Summary of possible mitigation methods for reducing the impact of underwater detonations on marine animals

Planning stage:	
Analyse recovery options	• Avoid underwater explosions whenever possible
Perform detonation risk assessment and develop mitigation strategy for detonations	• Modelling the radiation of sound and shock waves • Determine impact and safety zones • Analyse vulnerability of the affected sea area (gather information about e.g. seal haul-outs, bird colonies, occurrence of harbour porpoises, sensitive area for fish species (spawning grounds etc.) • Analyse options for time and place of detonations with less impact on the marine environment • Analyse the suitability of technical mitigation measures • Planning of pre-detonation and post-detonation surveys • Planning of observer scheme • Development of safety procedures for the marine environment
Measures before detonation:	
Pre-detonation survey	• Air based marine mammal survey in greater area of detonation site • Acoustic monitoring for harbour porpoises

Use of acoustic deterrents for marine wildlife	• Effectiveness depending on the species' behaviour and individual motivation to stay in the area • Development of a site specific deterrent strategy including use of harbour porpoise pingers for the area close to the detonation site and seal scarers for harbour porpoises at larger distance • Seal scarers are not well-suited for seals • Explosive "scaring charges" are not recommended because their scaring effect is not proven and they can also be harmful for marine life
Measures during detonation:	
Bubble curtain	Some critical factors: • air volume stream • diameter of the air bubble ring • water depth • oil free compressors to avoid oil pollution • performance monitoring by pressure sensors inside and outside bubble ring
Other sound absorbing measures	• rigid or collapsible shockwave shaper (experimental) • detonation of munitions within a crater • detonation close to the surface • detonation shielded by islands/flats • detonation in shallow water or on sand banks
Protected-species observers	• Visual monitoring • passive acoustic monitoring (PAM) for harbour porpoises • effectiveness depending on light conditions, sea state and biology/behaviour of the species
Measures after detonation:	
Post-detonation survey	

The figure below lists mitigation options discussed during a mitigation workshop in November 2013 (von Benda-Beckmann et al. 2014). Some of these options still require more research to assess their effectiveness and applicability. Others have the disadvantage of uncontrolled introduction of additional munitions constituents in the sea (e. g., deflagration).

	Source		Sound propagation		Animal
A	Move the source to different location (shallow, less populated areas)	H	Shielding, bubble curtain	N	Deterrent devices
B	Detonate in air at sea	I	Shielding, air pocket	O	Timing, season with low animal density
C	Deflagration	J	Shielding, burying with sand	P	Monitoring (visual/ acoustic)
D	Jet-cutting	K	Timing, low tide		
E	Multiple sequential explosions	L	Shielding, air pocket due to small charges		
F	Change policy to avoid detonation	M	Shielding, resonant air-filled spheres		
G	Detonate close to surface				

Figure 13: Mitigation options discussed during a workshop in November 2013

4.4.3.1 Detonation risk assessment and mitigation strategy

Before blasting, a proper **detonation risk assessment and mitigation strategy** should be developed in order to protect the marine environment. Such a detonation risk assessment (not to be confused with the overall risk assessment in 4.1.3) includes a thorough determination of possible impact zones (for injury and hearing impairment) and pre-detonation surveys to analyse which species would be affected by high order detonations. Seal haul-outs, seabird colonies, occurrence of harbour porpoises, sensitive areas for fish species (spawning grounds etc.) are of special concern, as these are especially vulnerable to the shock waves originating from detonations. In the planning stage it should be determined how most vulnerable areas or time frames can be avoided by postponing detonations or relocating the detonation site.

A site-specific shock wave and noise propagation model is required in order to estimate the impact zone. An adequate safety margin should be established as part of the safety procedures in a precautionary manner. Pre-detonation surveys (air or ship based, passive acoustic monitoring) are necessary to assess, which animal species and how many animals would be affected and whether it is possible to keep them at safe distance (cf. Yelverton et al. 1973, 1975, Goertner 1982, Thiele & Stepputat 1998, von Benda-Beckmann et al. 2015). Possible alternatives to blasting should be considered, and best available techniques be identified.

In order to safeguard protected marine species when executing high order detonations underwater, sensitive times and areas, in which these species occur in larger numbers or are especially vulnerable, should be avoided (Dolman et al. 2009). Substantial knowledge on the occurrence, life cycle parameters and behaviour of migrating species is essential to this mitigation measure. Known feeding, migration, nursery, spawning, summering or overwintering areas of sensitive species can be entered into data bases, that are used for planning and execution of clearance activities.

The implementation of a protected-species observer scheme in order to maintain a safe "exclusion zone" around the blast is another important measure to be performed before detonation. Certain regulations require observations starting as early as 48 h before a planned detonation using shipboard surveys for protected species as well as pre- and post-detonation aerial surveys (Gitschlag & Herczeg 1994, Clarke & Norman 2005, Viada et al. 2008). This measure relies on the thorough determination of possible impact zones, a skilled observer team, and suitable visibility conditions (calm sea, good light). More than one vessel is required to observe the whole exclusion zone, which may have a radius of several kilometres (Clarke & Norman 2005, Dos Santos et al. 2010, von Benda-Beckmann et al. 2015). For small cetaceans such as harbour porpoises, visual and passive acoustic monitoring (PAM) should be used in combination. However, PAM is of no use if animals do not vocalise or are orientated away from the acoustic monitoring device. Seals can be monitored acoustically only a short period of the year as they mainly vocalise during the mating period (Van Parijs et al. 1999). Protected-species observers can only be regarded as one of several components of a comprehensive mitigation strategy because the method is very dependent on conditions and affected species.

4.4.3.1 Scaring Charges and Noise

The use of acoustic deterrents serves the purpose of producing noise, with the aim of establishing an exclusion zone around a site before the detonation is executed. The application of such means requires careful consideration.

The range of customary gillnet pingers is only a few hundred meters, and it only deters certain species, such as the harbour porpoise (e.g., Culik et al. 2001). A better option are DDD (dolphin deterrent device) pingers, which have to adjusted to the species, which is to be deterred from a detonation site. Of the three sounds DDD pingers produce, one can be considered effective for harbour porpoises. However, systematic studies of the deterrent effect and range with respect to harbour porpoises are lacking.

Seal scarers are much less effective with respect to seals when compared to harbour porpoises. Thus, it is not recommended to rely on the deterrent effect to seals. Mikkelsen et al. (2017) experimentally found that harbour porpoises exhibited avoidance reactions at ranges of up to 525 m from sounding seal scarers with a reduced acoustic output. Contrary to this, seal observations even increased during sound exposure within 100 m of the loudspeaker. Results of different studies with respect to seal scarer effectiveness to seals are contradictory (Jacobs & Terhune 2002, Fjälling et al. 2006, Graham et al. 2009). The strong repellent effect on harbour porpoises has however been confirmed in multiple studies (Olesiuk et al. 2002, Johnston 2002, Kastelein et al. 2010, Brandt et al. 2013, Mikkelsen et al. 2017). For marine mammals, the motivation to exploit a food source and habituation seems to influence the scale of avoidance of seal scarers. In no case does the effective deterring range cover the full impact zone of injury and hearing loss when detonating a large charge such as a mine, water bomb or torpedo head. The conclusion of these findings is that scaring devices are only suitable as an additional measure for mitigation, e.g. in combination with a bubble curtain. Acoustic scaring devices are not suitable for deterring birds, reptiles, and fishes (e.g., Melvin et al. 1999).

Explosive "scaring charges" are not recommended as their scaring effect is not proven. Fish scaring charges of 20 g were used during munitions clearance for the Nord Stream pipeline in the Baltic Sea (Nord Stream 2011). However, the scaring effect of such charges is questionable as no flight response has been reported in experiments conducted so far (Lewis 1996, Keevin & Hempen 1997). It must further be considered that, similar to the effect on human divers, even a charge of less than 20 g can be harmful to marine life at ranges of up to a few hundred meters (Young 1991). Depending on the size of the charge, the fish species and distance between charge and fish, scaring charges may thus contribute to fish mortality. Moreover, in areas where detonations occur on a regular basis (such as the Gulf of Mexico, where explosives are used for the common but debatable practice of decommissioning oil and gas platforms), marine mammals or birds could be attracted by scaring charges. They might learn that following detonations, leads them to killed or debilitated fish, which are an easy to exploit food source. They could therefore be subsequently exposed to further explosions (Continental Shelf Associates 2004, Danil & St. Leger 2011).

4.4.3.2 Bubble Curtain

Among the technical mitigation measures, bubble curtains can be considered best environmental practice, because they show the best potential to reduce impacts of shock wave on marine wildlife and because they can be combined with other mitigation measures. Bubble curtains are generated by releasing pressurised air from a nozzle pipe ring that is located on the seafloor. The bubbles rise to the surface and thereby form the circular curtain. It has been shown in various experiments and applications that air bubbles in the water effectively reduce the sound pressure and the shock wave from a detonation (Notarbartolo Di Sciara 2002, Nützel 2008, Schmidtke 2010). In the German EEZ, the use of bubble curtains is mandatory for the execution of high order detonation during offshore windfarm construction. Bubble curtains are also recommended by numerous nature conservation agencies in the United States for the protection of rare or commercially relevant fish species (Keevin et al. 1997, Keevin & Hempen 1997, Keevin 1998). Damping effects of bubble curtains can be explained by adiabatic compression of the bubbles resulting in a temperature rise, the oscillation of bubbles and the loss of energy due to viscosity and thermal transfer between bubbles and water, emission of rarefaction waves by each bubble, and decrease of shock velocity due to compressibility (Grandjean 2011). The efficiency of bubble curtains depends on their diameter, width and shape, air volume stream, bubble size, and on water depth. The performance of a bubble curtain can be monitored by using pressure sensors located inside and outside the bubble ring.

Bubble curtains can substantially reduce the impact zone for marine organisms, provided that their radius is large enough. In reducing piling noise during offshore construction, it is state of the art to deploy a nozzle ring of up to 1600 m in length (C. Grunau, Hydrotechnik Lübeck, pers. comm.). A bubble curtain with a radius of 22 m used in the detonation of a 300 kg mine containing “Schieβwolle 39” (45% TNT + Al) has shown to be ineffective as it did not reduce the peak pressure at all (Schmidtke et al. 2009), whereas a bubble curtain with a radius of 70 m reduced the peak pressure of the shock wave by 16 to 19 dB re 1µPa (Schmidtke 2010). Given the sound propagation properties in water, a bubble curtain this size would reduce the radius of the impact zone by approximately by approximately one order of magnitude and the area affected by some 98%.

However, even a damped shock wave can harm marine life with the remaining pressure. Furthermore, it needs to be mentioned, that any detonation, especially of old ammunition, releases toxic munitions constituents into the water due to incomplete combustion. This cannot be prevented using a bubble curtain (Pfeiffer 2009).

4.4.3.3 Other dampening strategies

In shallow waters, other dampening strategies could be applied. A part of the energy could be redirected to the surface by positioning the ammunition in a crater. However, this practise is much less effective than a bubble curtain. Another approach is to lift UXO items close to the surface (von Benda-Beckmann et al. 2014). Furthermore, the placement of a rigid ring (cofferdam) around the munitions (rigid shockwave shaper) or an air cushion on the top (collapsible shockwave shaper) (for fundamentals, see Wallace 1982) have been discussed as options. However, these approaches require further development and examination of their shockwave reduction potential.

4.4.4 Salvaging

The best option for avoiding negative impact to the marine environment in general and marine vertebrates in particular is to recover the warheads instead of blasting them in place (Koschinski & Kock 2009). Some new methods and technologies have been presented at the three International Dialogues on Underwater Munitions and the MIREMAR conference (Minimising Risks for the Environment in Marine Ammunition Removal in the Baltic and North Sea, Neumünster/Germany, 16-18 November 2010, www.miremar.de) including remotely operated salvage robots, underwater jet cutting, in situ destruction in mobile detonation chambers or treatment of energetic compounds using ultraviolet radiation as well as transport or treatment in salvage pressure containers or reactors. However, all of them still require further development. With current technologies it is not always possible to use recovery methods, as certain ammunition items are not safe to handle. Detonations may be necessary when the safety of personnel dealing with the munitions cannot be adequately assured. The monetary expenses of utilising safe recovery methods rather than detonation, should not be the only determining factor because true costs (e.g., for environmental damage or damage/contamination of commercial stocks) may far outweigh the immediate expenses.

4.4.4.1 Extraction by Dredging

Extraction by dredging is the underwater surface abrasion of sediments and smaller UXOs. It constitutes a full volume clearance, during which a previously defined area is completely swept up to a certain depth. The dug-out material (dredge spoil) is analysed for UXOs, which are removed before the sediments are dumped again. As the BMUB catalogue (2014) explains, larger UXOs have to be identified and extracted before extraction by dredging takes place (e.g. manually by divers). For the dredging process, safety standards are to be chosen in a way that loss of equipment and injury of workers can be excluded. Therefore, the largest potential explosion (unintended, due to the mechanical stress during dredging) has to be anticipated (BMUB and MMVg, 2014).

Dredging operations can be performed with clamshells (dredge spoil is loaded on tug) or suction (dredge spoil flushed through pipes) (Schwartz and Brandenburg, 2009). The separation of explosive items can be done either by using a strainer with a mesh size appropriate to filter out the smallest relevant UXOs (to be defined beforehand based on survey and UXO identification) or by a combination of geophysical measures (magnetometer) and eye-sight (BMUB and MMVg, 2014). Disadvantages of Dredging include the very high costs, heavy disturbance (destruction) of local marine environment, and increased efforts for workers' safety given that spontaneous detonation cannot be disregarded as a possible risk (BMUB and MMVg, 2014).

4.4.4.2 Extraction by Electromagnets

The procedure of utilizing underwater electromagnetic extraction of UXOs, another full-surface recovery, is described by BMUB and MMVg (2014) as follows: Electromagnets with built-in flushing nozzles are fastened to a swimming platform (ship or pontoon) and lowered to the seafloor, where waterjets from the flushing nozzles drive the magnets into the ground. The maximum penetration depth depends on the seafloor sediment characteristics and usually does not exceed a few decimetres. Magnetic material is pulled towards the electromagnet and is thereby separated from the soil. New technologies allow monitoring and preventing possible losses during the extraction movements, where friction- and weight-induced resistances have to be overcome by the electromagnetic force. The extracted material is then brought up on the platform and UXO is separated from scrap material. Protection against spontaneous detonation has to be ensured. Several limitations have been detected by BMUB and MMVg (2014): The use of Electromagnets is only suitable for near-surface extraction in relatively loose sediments. Uncontrolled movements of explosives can lead to detonations and (with older equipment) to loss of items. Due to a magnetization of the area, a follow-up magnetometer scan is not possible.

4.4.5 Transport

Ordnance that is not safe to handle (e.g. with an armed fuse or a sensitive main charge such as picric acid) shall not be recovered aboard a manned vessel unless an appropriate containment system is used to mitigate the risk to personnel. (UNMAS, 2014) A general problem of the surfacing of munitions from deeper water levels is the sudden change of ambient pressure, which may for some explosives lead to spontaneous detonation, or for heavily corroded shells to mechanical failure and leakage (Pfeiffer, 2012). The transport containers mentioned above addresses this problem. Another risk posed by the surfacing and transportation on ship and land is the drying of UXOs. Pfeiffer (2012) describes that the complex and often unclear chemical constitution of old munition can potentially react when dried, therefore arguing for deliberate wet arrangements (Pfeiffer, 2012).

4.5 Other tools

4.5.1 Monitoring

5. National and International Efforts and Activities

5.1 HELCOM Members

5.1.1 International

5.1.1.1 Current Activities

DAIMON

DAIMON (Decision Aid for Marine Munitions) is an international project consisting of partners from Poland, Germany, Sweden, Finland, Norway, Lithuania and Russia, and cooperating experts worldwide, united by the goal to solve the problem of underwater munitions. This project is part-financed by the EU INTERREG Baltic Sea Region Programme 2014-2020. The question which DAIMON takes up is how to proceed with the identified and mapped warfare objects. Remediation or no action are subject to heated disputes among the decision-making bodies. Since there cannot be a general answer to this question, DAIMON will analyze identified and localized objects with artificial intelligence incorporating large amounts of spatial and non-spatial datasets based on latest scientific research. For each detected munition object, the software will formulate a risk assessment, incorporating information about the localization and overall state of the ammunition, the surrounding environment and state of biological pollution/damage. Furthermore, it will recommend possible actions, such as recovery & destruction, accumulation, encapsulation, capping, blasting or non-action.

DAIMON follows an integrative approach and incorporates the results of former projects (e.g. CHEMSEA) for an efficient use of data and a consecutive development of knowledge.

5.1.1.2 Past Activities

CHEMSEA

CHEMSEA investigated official and unofficial dumping sites using hydro-acoustic detection and magnetometric surveys to find links between objects on the seabed and magnetic field disturbances, to examine currents and to sample sediment so as to characterise the natural conditions of the sites. Mapping involved categorising objects, selecting those needing further investigation and feeding coordinates of munitions and contaminated sediment into maps.

Toxicity studies aimed to investigate biological uptake of chemical warfare agents (CWA) under varying conditions. Cages were deployed where the concentration of munitions was highest before accumulation and biological effects of chemical substances in fauna were measured.

CHEMSEA reviewed national CWA legislation and formulated guidelines for munition handling as well as hazardous waste and contaminated sediment disposal. A regional contingency plan was drawn up comprising of codes of conduct in the event of an accidental catch of chemical munitions at sea or their being washed up onshore. Models were developed for both scenarios, leading to the standardisation of national response procedures and plans.

Awareness levels of groups at risk of contact with CWA were evaluated, including fishermen and offshore workers. Training was aimed to spread knowledge of chemical munitions dumped at sea along with best practices for minimising threats.

<u>MODUM</u>

The Monitoring of Dumped Munitions (MODUM) project aimed to establish a cost-effective monitoring network to observe munition dumpsites in the Baltic Sea, using Autonomous Underwater Vehicles (AUVs) and Remotely Operated Underwater Vehicles (ROVs), and utilizing research vessels of partner institutions as launching platforms.

5.1.1.3 Authorities and Legal Situation

5.1.1.4 Societal Awareness

5.1.2 Estonia

5.1.2.1 Current Activities

5.1.2.2 Past Activities

5.1.2.3 Authorities and Legal Situation

5.1.2.4 Societal Awareness

5.1.3 Finland

5.1.3.1 Current Activities

5.1.3.2 Past Activities

5.1.3.3 Authorities and Legal Situation

5.1.3.4 Societal Awareness

5.1.4 Germany

5.1.4.1 Current Activities

AMUCAD

The Ammunition Cadaster Sea (AMUCAD) is a project developed by EGEOS GmbH in close consultation with the Ministry of Environment of Schleswig-Holstein. It deals with the acquisition, management and analysis of a wide variety of ammunition related datasets for the North and Baltic Seas. Therefore, a large amount of historical and modern datasets is acquired and integrated into the system and new technologies like artificial intelligence/visual analytics are used for interpreting and connecting these datasets. AMUCAD is part of several national (ERPAD) and international (DAIMON, NSW) research projects whose results will be implemented and further developed. It is designed for use in administration, research as well as businesses and provides a central information system for different applications such as marine spatial planning, offshore infrastructure development and monitoring of environmental aspects.

RoBEMM

Safe recovering procedures for large underwater munitions such as mines, depth charges and torpedo heads are currently developed under the collaborative project RoBEMM (Robotic underwater salvage and disposal process with the technology to remove explosive ordnance in the sea, in particular in coastal and shallow waters). The goal of this collaborative project is to develop an economically viable process and corresponding equipment which is ideally suited for use in coastal and shallow waters and will in future be able to uncover and identify detected objects as well as dispose of explosive ordnance in situ (under water) and fully automatically (without using divers) and without detonation. For this purpose, a supply platform with a low-cost WROV and processing unit will be developed and deployed. The project is executed by Automatic Klein GmbH, the Fraunhofer Institute for Chemical Technology, Heinrich Hirdes EOD Services GmbH (Coordinator) and the Institute for Infrastructure and Resources Management of the University of Leipzig.

UDEMM

In the framework of the UDEMM project, scientists of different partner institutions investigate four relevant aspects concerning the effects of underwater munitions. This project is conducted in close collaboration with the technology project RoBEMM in order to develop an economically viable, remotely operated and environmentally friendly method to perform in-situ (underwater) delaboration of UXO that are not safe to handle. The project is funded by the Federal Ministry of Education and Research (BMBF) within the special program "Research for Sustainable Development (FONA)" with approximately 1.6 Mio €.

Sea dumped munitions may contaminate the surroundings by releasing explosive chemicals due to corrosion and breaching or by detonation. An active biomonitoring study with transplanted blue mussels (M. edulis), that were placed in an area burned with explosive compounds (Kolberger Heide, Germany) in different heights above ground, over an exposure time of 93 days was performed. With this biomonitoring system, it was shown that blue mussels accumulate 2,4,6-trinitrotoluene (TNT) and its metabolites 2-amino-4,6-dinitrotoluene (2-ADNT) and 4-amino-2,6-dinitrotoluene (4-ADNT) in their tissues. In all mussels deployed at the ground, a body burden with 2-ADNT of 103.75 ± 12.77 ng/g wet weight and with 4-ADNT of 131.31 ± 9.53 ng/g wet weight was found. TNT itself was found in six mussels with an average concentration of 31.04 ± 3.26 ng/g mussel wet weight. In the mussels, positioned at one meter above the ground, no TNT nor 2-ADNT could be detected. However, 4-ADNT was found in those samples with an average concentration of 8.71 ± 2.88 ng/g mussel wet weight.

This is the first study using blue mussels M. edulis as an active biomonitoring system for TNT and its metabolites 2-ADNT and 4-ADNT in a free field experiment in a burdened area. Moreover, with this system, it was unequivocally proven, that these toxic explosives accumulate in the marine biota and in the marine food chain, thereby posing a possible risk to the marine ecosphere and human health.

<u>MUNITECT</u>

The Munitect network is an association of companies and research institutions, driving the development of economically effective munitions detection systems for underwater use. By means of cooperation, the different competences and experiences of network partners with varying industry backgrounds are accumulated and shared.

Within the scope of the network, its members initiate and develop application-oriented research and development projects in joint cooperation with national and international project partners. Their goal is to make a contribution to the goal of sustainably solving the problem of ammunition in the sea.

The network partners share the vision of a high-performance and cost-effective sensor platform, facilitating an efficient, safe and risk-free detection of ammunition. The system is to be developed in a modular fashion, in order to be able to identify different harmful substances or objects with various methods on site at the same time. This will result in significantly expedited ammunition detection. Improving the accuracy of object classification and the specific development of cost-efficient end systems are challenges, the network is approaching.

MineMoni

<u>Archival Work</u>

The German Military Archive in Freiburg stores 51 km of relevant files. A well-functioning team can check 5-6 m with nearly 350 individual files over the course of one week. Not all files are of interest. In a total of 16 research weeks from 2010 till 2018, 1,166 files with ammunition at sea were copied and scanned. Complemented by nearly 240 files from the UK National Archive in Kew and from the Royal Navy, a solid knowledge base could be established.

In 2018, two weeks were spent for research in the German Military Archive in Freiburg. Both teams scanned and copied a total of 25.917 pages of nearly 650 different documents. Immediately afterwards the check of the documents started; a process that is not finished by today. Nearly 40% of the obtained documents are from WWI, mostly from the central and east Baltic Sea, 55% from WWII and 5% from the end of WWII and post-war time. The focus of WWI documents is on mine warfare in the central and eastern Baltic Sea and artillery fights in the area of the Baltic isles.

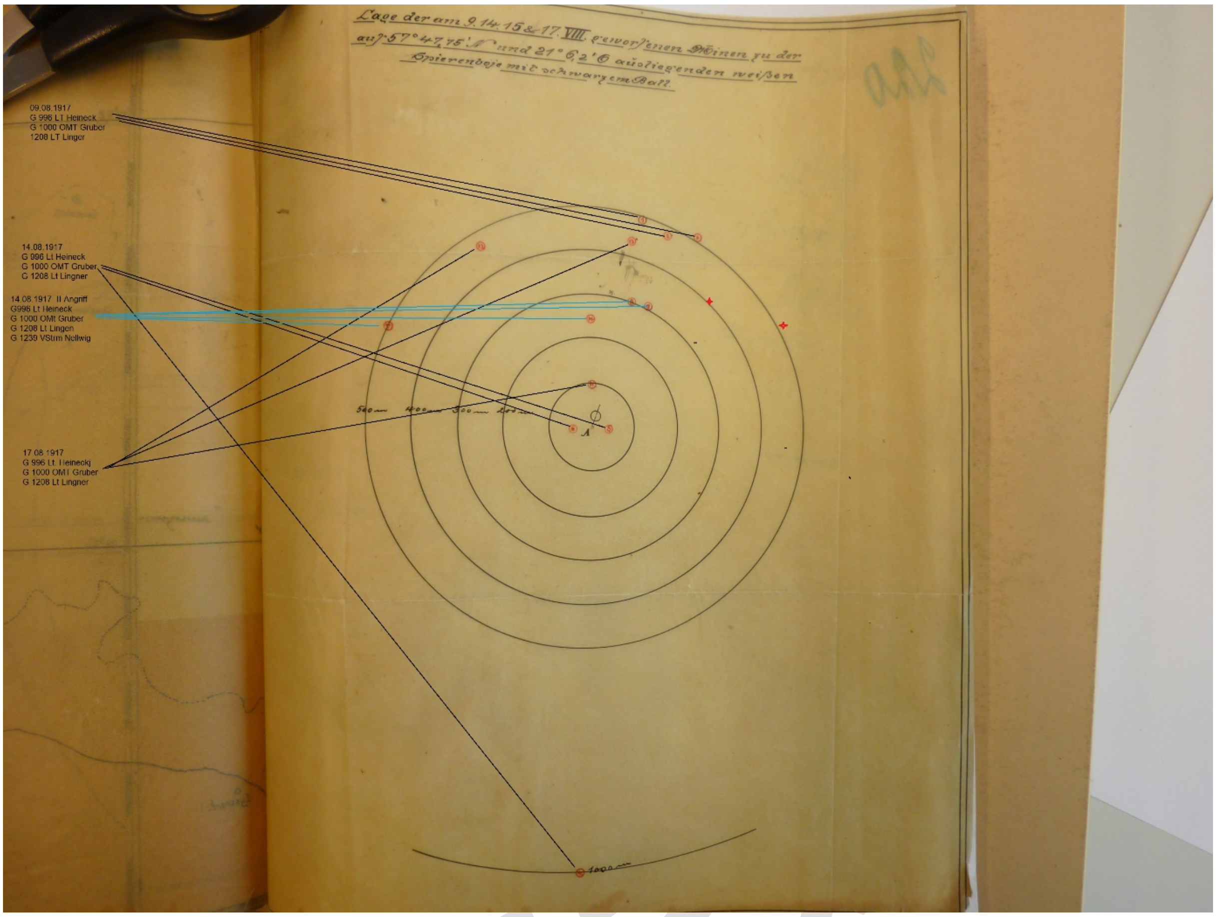


Figure 14: Archiv work Open Spirit 2018 Teka Mine

The focus of WWII documents is on mine warfare and air defence in the western Baltic Sea. They contain a large number of pages regarding minesweeping in the entire Baltic Sea, air strikes and artillery fights. The research included, collecting the information regarding air-defence alongside the German coastline against the Allied bombers and the calculation of misfired artillery shells. Some additional documents were found that provide information about the storage of ammunition during the final months of war and the way to the dumping areas.

5.1.4.2 Past Activities

5.1.4.3 Military Activities

<u>OPEN SPIRIT 2018</u>

The first operation OPEN SPIRIT in 1998 was developed from the former operation Baltic Sweep. Baltic Sweep was a bilateral exercise between the German Navy and the Latvian Navy in1996. In this operation, three German minehunters checked an area in front of the entrance to Riga Harbour. 21 mines were found and disposed. One year later, the Royal Swedish Navy joint the operation to check the same are as in 1996.

In 1998 The operation got a new form. The operation area was in Estonian territory waters and 5 nations, Estonia, Germany, France, Belgian and the Netherland participate in a common work and disposed 31 mines. From this time, the operation OPEN SPIRIT was held every year in the waters of Estonia, Latvia and Lithuania. But the aim was and is always the same: Reduce the risk at Sea from dumped ammunition.

The result of all operation was dominated from disposed mines. Mostly moored mines and a smaller number of ground mines from Germany and Russia, were disposed. A special branch were some captured France and Netherland mines in WW II. Reactivated by German Navy, the mines were laid in the “NASHORN” minefield between Tallinn and Helsinki. Other ammunitions as torpedoes, depth charges, antisubmarine rockets, and artillery shells were found, marked and disposed.

In 2018, OPEN SPIRIT took placed in Estonian waters. From 11. to 25 may, 17 units with a crew of 800 sailors found and disposed 90 mines, bombs, torpedoes, depth charges and artillery shells. The three oldest objects were two German airdropped TeKa-mines and one UC 200 mines, all three were laid in August 1917.The TeKa mine was develop for laying by submarine, but the transport system in the submarine torpedo tube don´t work correct. A first try to lay the mine with airplane was successful and the decision for the first airdrop minelaying was given to the Fliegerstation Windau. Airplanes from type Gotha laid in July and August 1917 in the north part of Irben Strait 72 TeKa mines.

Figure 15: Open Spirit 2018 LMB Mine

Similar as BALTIC SWEEP and OPEN SPRIRIT operations were the Swedish- Estonian-Latvian and Lithuanian Mine Countermeasure Operations. From 1995 till 2009, the Royal Swedish Navy and the Navies from the three Baltic States reduced the risk of ammunition with bilateral, later joint by NATO Forces, operations. In 18 operations 670 UXOs were found, marked, documented and disposed. The operations areas were the territorial waters from the three Baltic states.

5.1.4.4 Authorities and Legal Situation

Overview

The German Federal Government in general is (beside others) responsible for defence, including civil defense, and the integrity of the state border, on land and at sea. This includes safety and security in the German EEZ to a far extend. In addition, the federal level takes care for safety of sea traffic in almost all parts of Germany, accessible for maritime vessels.

Federal services tasked with this are

- German Armed Forces (www.bundeswehr.de)
- German Federal Police (www.bundespolizei.de)
- German Customs (www.zoll.de)
- German Waterways Administration (WSV - www.wsv.de) and the
- German Federal Maritime and Hydrographic Agency (www.bsh.de).

On land and in the German territorial waters the five coastal states of Germany are tasked with law enforcement, safety and security, with one exception: Safety of maritime traffic remains with the Federal level, responsible is the German Waterways Administration.

Relevant state and municipal services are

- State Police,
- County rescue service, (voluntary) county and/or municipal fire departments and the
- States, county's or municipal's administration,

depending on if the warfare material contamination occurs in a harbour area, estuary, beach or open coastal water.

To cope with this challenging legal system, the Federation and the coastal states have established the Central Command for Maritime Emergencies (CCME - https://www.havariekommando.de) in Cuxhaven, as a 24/7 central access to multiple maritime agencies in Germany. German Waterways Police Reporting and Coordination Centre, integrated in CCME, serves as national point of contact for encounters of munitions in the sea.

The authorities involved emerge from the location of the study area. In the course of ordnance disposal, the requirements of the authorities are met. If these requirements contradict this quality guideline, the requirements of the authority apply. If the requirements of the authority fall short of the requirements of this quality guideline, the requirements of the quality guidelines should be met.

UXO Removal

In their respective territorial waters, the bodies listed here can monitor requirements for the processes and on board the vessels used. If new technologies are used as part of the disposal of ordnance or if contractors hitherto unknown are commissioned, it is recommended to monitor the work on board the vessels used by the authorities listed here.

Within German territorial waters, the entities listed in Table 2 are responsible for the disposal of ordnance. They also assess how to deal with suspicion points that have already been found, if an adjustment of the area of interest occurs as part of the elimination of ordnance. The places listed in Table 2 can perform individual processes themselves.

Table 2: Küstenbundesländer und für Kampfmittelbeseitigung zuständige Stellen

Bundesland	Zuständige Stelle	Rechtliche Grundlage
Hamburg	Kampfmittelräumdienst der Feuerwehr Hamburg	Verordnung zur Verhütung von Schäden durch Kampfmittel (Kampfmittelverordnung - KampfmittelVO)
Mecklenburg-Vorpommern	Munitionsbergungsdienst	Landesverordnung zur Verhütung von Schäden durch Kampfmittel (Kampfmittelverordnung)
Niedersachsen	Kampfmittelbeseitigungsdienst	Runderlass „Kampfmittelbeseitigung"
Schleswig-Holstein	Kampfmittelräumdienst	Landesverordnung zur Abwehr von Gefahren für die öffentliche Sicherheit durch Kampfmittel (Kampfmittelverordnung)

Outside German territorial waters, there is no competent authority for the disposal of ordnance. However, there are responsibilities for the BSH for individual aspects of disposal of ordnance:

- The BSH approves research activities according to § 132 BBergG. Surveying requires such approval.

- In the case of blasting operations, the BSH assesses a process description for the execution of the blasting operations and the planned soundproofing measures.

Operational health and safety

Depending on the geographic location of the study area and the area of interest, the implementation plans drawn up in phases II and III as well as the protection concepts created will be presented to the bodies listed here for plausibility and opinion.

Within the German territorial waters, the labour protection supervisory authorities of the federal states are responsible for compliance with the Occupational Health and Safety Act.

Outside German territorial waters, the Federal Maritime and Hydrographic Agency (BSH), with the participation of the other bodies listed in Table 3, makes demands on compliance with the Occupational Health and Safety Act.

Table 3: Gebiete der AWZ und für Arbeitsschutz verantwortliche Stellen

Gebiet	Verantwortliche Stellen
Bereich der AWZ vor der Küste Niedersachsens	BSH, Gewerbeaufsichtsamt Oldenburg
Bereich der AWZ vor der Küste Schleswig-Holsteins	BSH, Staatliche Arbeitsschutzbehörde bei der Unfallkasse Nord
Bereich der AWZ vor der Küste Mecklenburg-Vorpommerns	BSH, Landesamt für Gesundheit und Soziales Mecklenburg-Vorpommern

In the case of incidents affecting occupational safety, the authority responsible for occupational safety and health in the legal area is informed.

Security of naval traffic

Depending on the geographical location of the suspicion points, the investigation of these suspicion points will be reported to the agencies listed here. In addition, these sites will be provided with information for the publication of messages for seafarers.

Within the German territorial waters, the registration takes place at the responsible waterways and shipping offices. The bodies listed according to the Electronic Waterway Information Service of the Federal Waterways and Shipping Administration publish the notices for seafarers

Outside of German territorial waters, the application is registered with the BSH. This also issues the news for seafarers.

Registration points

For some aspects of the disposal of ordnance, reports are made to various agencies.

The Maritime Security Centre has a central marine ammunition report office where all ordnance and ordnance reports are reported. Furthermore, the registration office will be provided with proof of the proper disposal of residual waste.

The BSH is notified of all ordnance discoveries and the handling of the ordnance. The BSH manages the national sound register for the North and Baltic Seas. Information about detonations carried out will be communicated to the BSH.

5.1.4.5 Societal Awareness

Another way to raise the attention of beach visitors is the hand out of “awareness brochures”. This has taken place for example at the beach area of Heidkate (Germany) in 2015 after several findings of explosives. Children had collected the explosive compounds and played with.

Example in German language

https://www.schleswig-holstein.de/DE/Landesregierung/POLIZEI/DasSindWir/LKA/Kampfmittelraeumdienst/_downloads/Handlungsempfehlungen_Munitionsfunde_am_Strand.pdf

5.1.5 Latvia

5.1.5.1 Current Activities

5.1.5.2 Past Activities

5.1.5.3 Authorities and Legal Situation

5.1.5.4 Societal Awareness

5.1.6 Lithuania

5.1.6.1 Current Activities

5.1.6.2 Past Activities

5.1.6.3 Authorities and Legal Situation

5.1.6.4 Societal Awareness

5.1.7 Poland

5.1.7.1 Current Activities

5.1.7.2 Past Activities

5.1.7.3 Authorities and Legal Situation

5.1.7.4 Societal Awareness

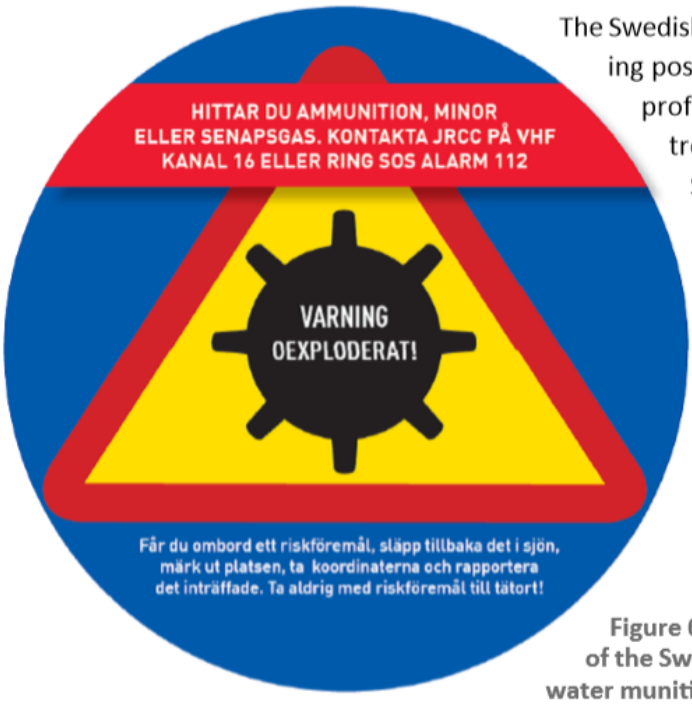
5.1.8 Sweden

5.1.8.1 Current Activities

5.1.8.2 Past Activities

5.1.8.3 Authorities and Legal Situation

5.1.8.4 Societal Awareness



The Swedish working group identified the following possible risk groups: recreational divers, professional divers and sub-surface entrepreneurs; professional fishermen; Swedish harbour workers; and rescue and alarm services professionals (HELCOM 2011b). The group has produced a sticker, a pamphlet, an advertisement and an educational package (Figure 6).

Figure 6: A munitions awareness sticker - part of the Swedish information campaign on underwater munitions (HELCOM 2011b).

https://www.kustbevakningen.se/hallbar-havsmiljo/miljoraddning/andra-skadliga-amnen/oexploderad-ammunition-till-sjoss/

5.2 Other Bodies active in the HELCOM Area

5.2.1 BOSB

5.2.2 NATO

5.2.3 UN

5.2.4 EU

JPI Oceans

As a result of discussions between the most relevant stakeholders, it has been decided that JPI Oceans will conduct activities along three lines:

Science Support- By combining different scientific disciplines, JPI Oceans intends to support the development of a service to forecast changes in the sea state in relation to munitions. Simulation of the impact of removal, dispersion and detonation on human health, on the environment, and on economic activities will also be investigated.

Technology Transfer- JPI Oceans will analyse different technologies and procedures for intervention to support decisions by operators and policy makers. The development demonstration of technologies and procedures can be used to increase safety, improve the efficacy and reduce the environmental impacts of interventions. JPI Oceans will provide support to exchange findings between different disciplines, projects and initiatives.

Exchange of Knowledge- Panels of experts will support transfer of knowledge and experiences of dealing with munitions in the sea.

6. Conclusions

6.1 Progress made since XXXX

6.2 Overall awareness and acceptance

6.3 Gap Analysis and Identification of Requirements

6.3.1 Geographic Distribution

6.3.2 Properties of Warfare Materials

6.3.2.1 Explosives

6.3.2.2 Toxicology

6.3.3 Effects and Risks of Warfare Materials

6.3.4 Assessment Methodology

6.3.4.1 Historic Reconstruction

6.3.4.2 Risk Assessment

6.3.5 Technological

6.3.5.1 Monitoring

6.3.5.2 Detection

6.3.5.3 Clearance

6.4 Primary Open Questions

7. Recommendations

7.1 International Efforts

7.1.1 International ammunition cadastre

An integral part of coordinating efforts is a centralized ammunition cadastre including results of previously conducted and ongoing research, management and analysis options for historic data from archives as well as risk determination and monitoring tools for decision making regarding UXO management and for monitoring of affected areas. The following functionalities should at least be provided:

- Mapping of so far known historic datasets (maps, documents, reports) which include spatial information;
- Recording, management and analysis of historic documents/texts based on actual data/text mining technologies
- Management and visualization of actual datasets (bathymetry, side scan, geomagnetic, video) for evaluation, analysis and monitoring purposes;
- Spatial planning capabilities for administrative use;
- Incorporation of relevant national and international datasets (e.g. wind parks, Cabel, pipelines etc.) from centralized data portals (EMODnet, HELCOM Data & Maps) and national authorities;
- Risk determination and decision support tools following integrated assessment approaches;

7.1.2 Research

Topics: toxicology, monitoring, environmental impacts, status assessments, risk management

7.1.3 Archive work

Topics: national and international archive work and context-based interpretation

7.1.4 Marine spatial planning

Marine spatial planning is a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that have been specified through a political process.

Topic: Ammunition its effects on humans and environment should be an integral part during national and international processes of marine spatial planning

7.1.5 Harmonizing definitions

7.1.6 European Quality Initiative

Three ways of endorsing high quality execution of offshore UXO treatment were identified. These ways encompass the generation of a European quality guideline, the establishment of a dissemination platform and the provision of offshore testing infrastructure. Central to all these ways of endorsement is the internationalization of upcoming efforts, due to the international nature of the industry that is targeted by the quality initiative.

Firstly, European quality guideline should be developed. However, it must not be a simple translation of the existing German document. Its generation needs to be subject to a widening of scope in order to be able to account for the situation of all European countries as regards their UXO history and distribution, the natural condition of their affected waters and their legal and normative situation. A sufficiently abstract document will be necessary. This document shall be accompanied by instructions on how national groups can deduce a national document, that meets their own specifications. This European quality guideline should be adjusted and updated in regular intervals.

Secondly, a dissemination platform for the exchange of information should be established. This platform may be both physical and digital. Annual quality workshops could be conducted. They have the potential to facilitate the dialogue between affected stakeholder groups and across nations. This way a multitude of different perspectives are contributed to the discussion of best practices and high quality execution of UXO treatment. Based on feedback by participants of the dissemination platform, workshops might be organized, that cover selected focal areas. The workshops may be coupled with a symposium, that serves as a gateway to provide scientific findings and progress to the industry and to facilitate corporation between research bodies and private companies. Results and insights that are gained during the workshops or symposia, may be published and organized using a web platform. The web platform could furthermore be used as a library for questions regarding UXO treatment but also as a means of communicating about practical challenges and newly applied solutions.

Finally, further emphasis should be placed on providing testing infrastructure, that is necessary for conformity assessment. Tests may be conducted for equipment, in order to validate its technical parameters or to verify its suitability for specific tasks. They may also be conducted for companies, giving them the opportunity to prove their ability to execute selected processes of UXO treatment. These tests would increase confidence of employers and authorities in UXO survey and clearance companies and allow for a certification of products or companies. In addition, UXO service providers could test their equipment for its applicability in certain scenarios.

7.1.7 Harmonizing UXO risk management

It should be aspired to find a common foundation for risk management in the offshore UXO context. Currently a discrepancy between probabilistic and deterministic approaches to risk assessment exists. Furthermore, a gap between the methodological potential of risk assessment and the application of risk based approaches in reality is apparent. These gaps can be closed by assessing the requirements for a risk assessment taking place in the context of offshore UXO treatment and comparing them with existing approaches that are applied in other industries. The result could be the development of new approach or the adaptation of an existing one, that can be found in the existing methodological catalogue.

7.2 National Efforts and Target Definition

Proactive spatial planning of construction work in munitions-contaminated waters including rerouting of pipeline and cable corridors or relocation of offshore structures can help minimising underwater detonations.

7.2.1 Programme of measures

7.2.2 Monitoring programme

7.2.3 Identification of areas of concern

Appendix

- Typical munitions of Baltic Sea
- Typical munitions compounds

Glossary

Benthic	Refers to the lowest level of the water column including the seafloor
Effect	A change that is a result or consequence of an action or other cause
Impact	The action of one object coming forcibly into contact with another
Impact zone	
Pelagic	Refers to the water column or the open sea, it consists of only water and the organisms living in it.
Sediment	Particulate matter that is carried by water or wind and deposited on the surface of the land or the seabed
UXO	Unexploded ordnance

Needs to be completed