DAM GERMAN MARINE RESEARCH ALLIANCE

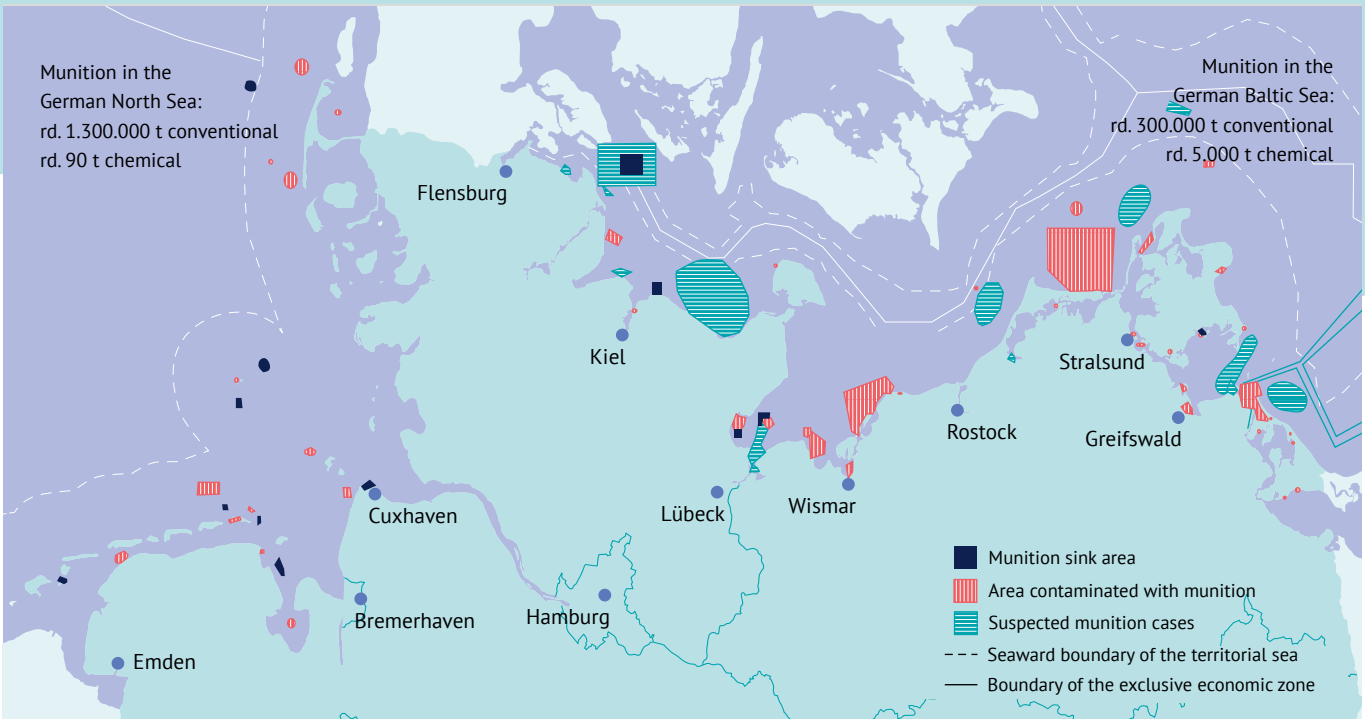
MUNITION IN THE SEAS

Current Knowledge and Perspectives

Munition in the seas and oceans are a threat to the marine environment and an impediment to their sustainable use. For several years, research has been conducted to evaluate the scale of the impacts and to develop solutions for their future remediation. In this paper, the current scientific knowledge is summarized along with perspectives on how to deal with marine munition.

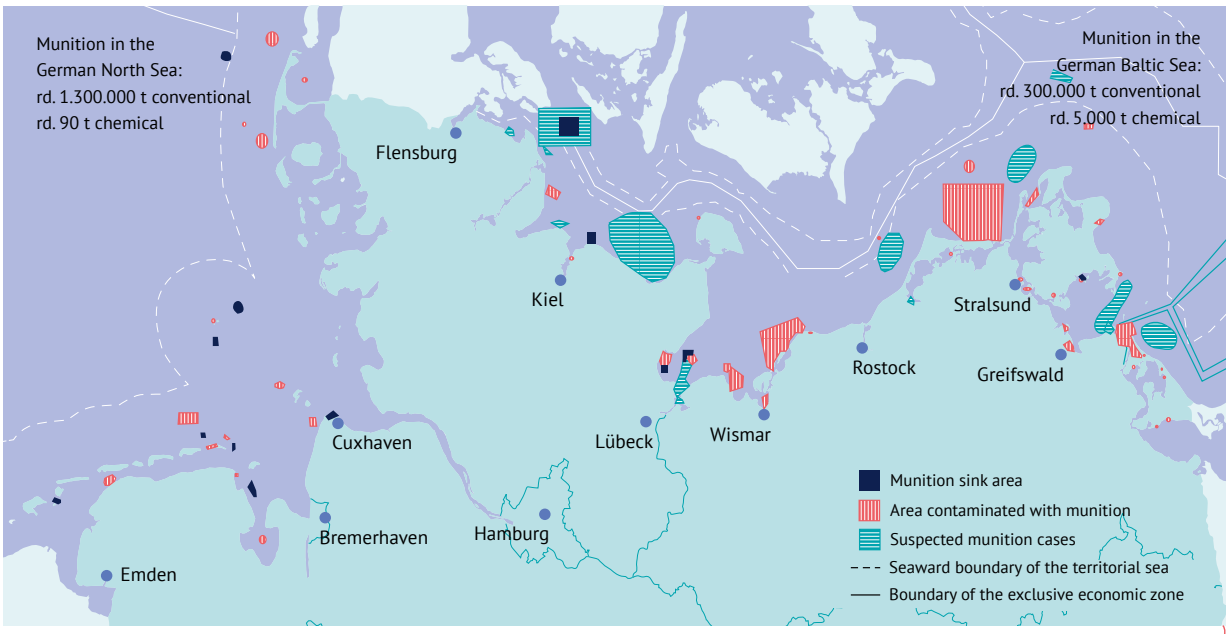
As of: October 2022

CONTENT



1 HISTORIC BACKGROUND AND MUNITION DISTRIBUTION

After World War I and II, large amounts of munition were dumped in German territorial waters and the German exclusive economic zone (EEZ). By far the largest amount of munition after WW II was sunk in dedicated dumping areas. Experts assume that a total of 1.6 million tonnes of conventional munition were dumped. This number is uncertain but appears realistic considering the German munition stock at the end of WW II. Furthermore, an expected 5,090 tonnes of chemical munition and warfare agents were dumped in German waters. In addition to defined dumping areas, conventional munition entered the seas during combat, military manoeuvres, and accidents at sea, although exact numbers and locations are difficult to assess.



Stress points: Munition in German marine waters (Böttcher et al. 2011)

CHALLENGES AND SOLUTIONS

The military archive in Freiburg contains several kilometres of potentially relevant historical documents. Additional information lies in archives of the Allies, especially in the United Kingdom. The largest portion if these documents is not digitised. It is thus recommended that any large-scale munitions clean-up begins with a systematic digitalisation of relevant documents and further historical research.

LINKS

- → *Böttcher et al. 2011: Bericht Munitionsbelastung der deutschen Meeresgewässer*
- → *north.io GmbH: Munitionskataster AmuCad.org*
- → *Land Schleswig-Holstein: Munitionsbelastung der deutschen Meeresgewässer (www.munition-im-meer.de)*

2 THREAT TO HUMANS

Similar to munition on land, marine explosive ordnance poses a threat to people who come into contact with it. Although an accidental detonation, e.g. during anchoring, is rather unlikely, the possibility exists as a latent threat. People and commercial entities who actively interact with the seafloor are certainly subject to higher risk of accidentally interacting with munition. This includes, among others, fisherpersons and people in the dredging industry. In addition, tourists can find parts of munition objects, explosives or white phosphorous on beaches. By profession, employees in public and private explosive ordnance disposal (EOD) squads face the highest risk. Finally, since the largest amount of dumped munition lies close to the coast in rather shallow waters, it could come into the possession of unauthorized people.

CHALLENGES AND SOLUTIONS

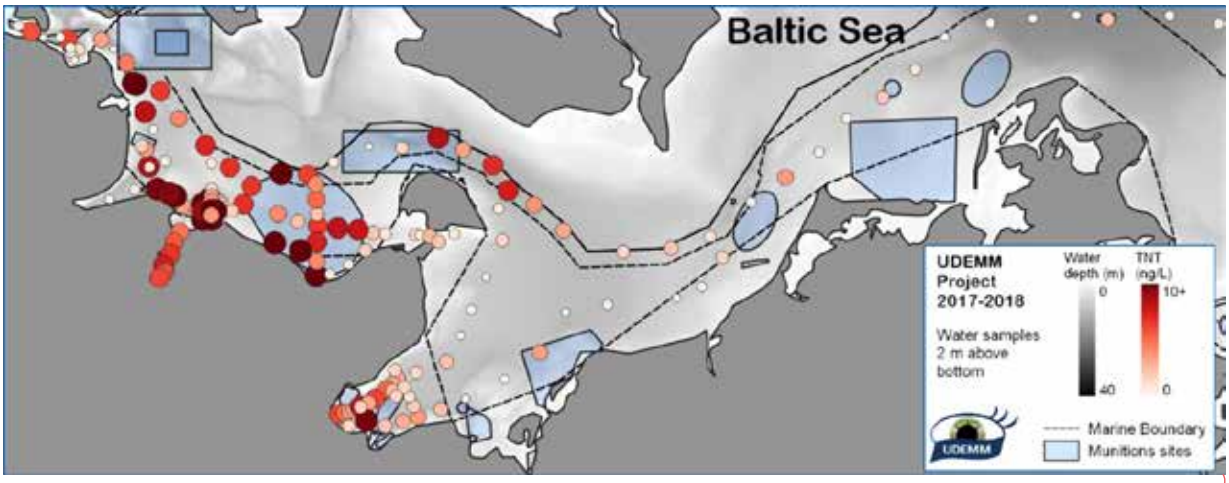
Research suggests that the impact sensitivity of explosives increases after contact with sea water for an extended period of time. Hence, munition could detonate more easily due to mechanical impact during accidental encounters or clearance operations. More data on this issue should be acquired in the future.

LINKS

→ *Pfeiffer 2012: Changes in Properties of Explosives Due to Prolonged Seawater Exposure*

3 ENVIRONMENTAL IMPACTS

Many explosive compounds are carcinogenic and mutagenic (e.g. TNT and its metabolites). Munition objects on the seafloor have been corroding for at least 77 years, and some dumpsites have large amounts of open explosive material present. Here, dissolved munition compounds can be detected in the water, sediment, and biota. Dissolved TNT concentrations close to exposed explosive surfaces can be 10 to 100 times higher than in comparable areas without munition contamination. Similarly, mussels from munition-contaminated areas show increased tissue concentrations of TNT and TNT metabolites compared with other areas. In addition, TNT and its metabolites have been found in the liver of flat fish near munition dumpsites, clearly demonstrating that munition compounds accumulate in marine biota.



TNT concentration in the German Baltic Sea (© Beck)

CHALLENGES AND SOLUTIONS

Currently, it is unclear whether munition compounds are transported through the food web, magnify in higher trophic levels, and end up on the plate of seafood consumers. The CONMAR project, which is part of the DAM Research Mission "Protection and Sustainable Use of Marine Areas", seeks to answer this question. A dedicated and regular monitoring programme is required to evaluate any future increase in human seafood consumer exposure to munition-related chemicals.

LINKS

- → *Greinert et al 2019: Praktischer Leitfaden zum Umweltmonitoring von konventioneller Munition im Meer*
- → *Bełdowski et al. 2021: Dumped munitions in the sea: fate, impacts and risks*
- → *Maser and Strehse 2020: Don't Blast*
- → *Maser and Strehse 2021: Can seafood from marine sites of dumped World War relicts be eaten?*
- → *DAM-Forschungsmission „Schutz und nachhaltige Nutzung mariner Räume"*

4 MARITIME ECONOMIC IMPACTS

Most offshore economic activities avoid known munition dumping areas. The munition dump sites are relatively small so that economic development in these areas is currently not necessary. Yet, whenever offshore activities interact with the seafloor, e.g. for technical installations (see section 1), detailed munition mapping is required and is potentially followed by a munition clearance operation. This issue is highly relevant for offshore renewable energy development. The cumulative cost of past clearance operations is unknown, but created technical innovations which precede development of technical methods to make the clearing of munition dump sites feasible.

CHALLENGES AND SOLUTIONS

The projected growth of the offshore energy sector in Germany and internationally will likely strain available technical and personnel capacities for munition removal and disposal. This would slow down the planned energy transformation. Thus, a new education and training scheme for EOD experts needs to be established soon.

5 MUNITION DETECTION SURVEYS

Several simultaneously usable methods exist to survey the seafloor for munition objects (magnetometers, seafloor mapping sonars, sub-bottom profilers). These surveys are typically undertaken by dedicated offshore mapping companies. During past and ongoing research projects, a number of dump sites particularly in the Baltic Sea have been mapped and investigated. These systematic investigations covered an area that – according to historic records – is presumed to contain 100,000 tonnes of conventional munition. Additional dumpsites totalling more than 200,000 tons of munition remain to be surveyed.

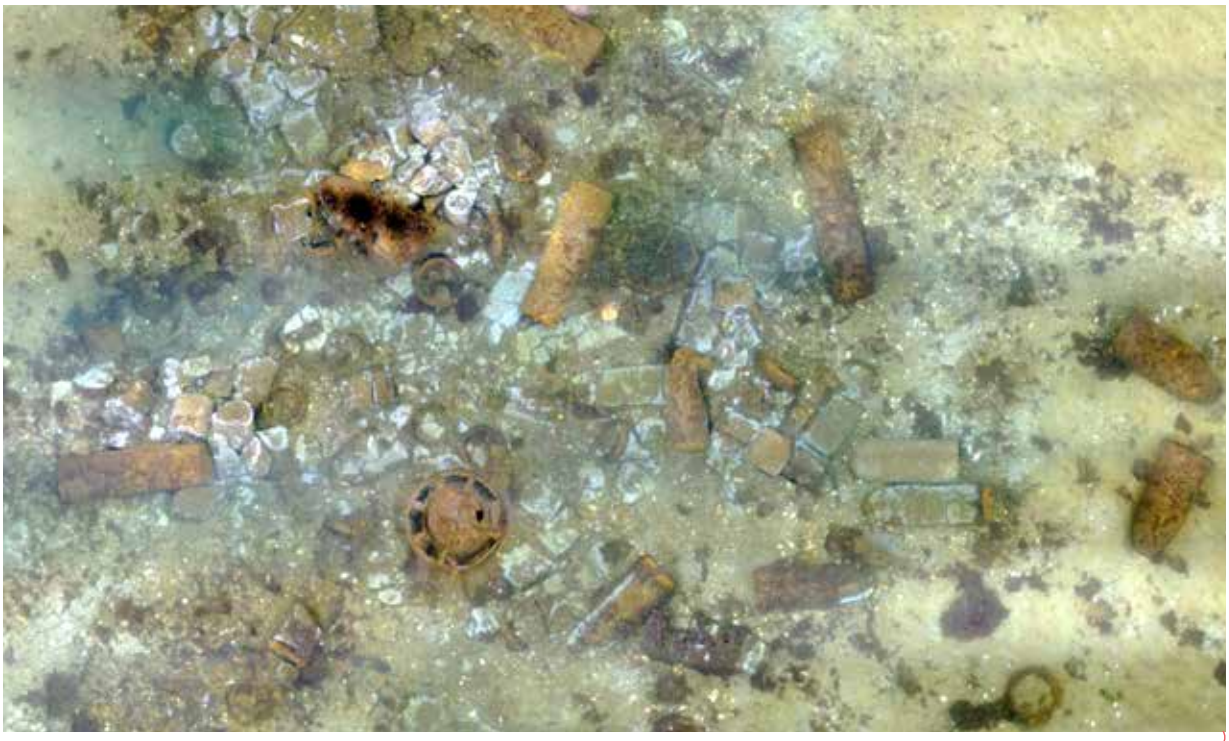


Photo mosaic of an ammunition pile in the dumping area in the Kolberg Heath (© GEOMAR)

CHALLENGES AND SOLUTIONS

Further advancements in sensor technology would be useful. However, more urgent development opportunities focus on autonomous data acquisition with autonomous underwater vehicles (AUVs) rather than ships, as well as AI-supported data analyses and interpretation. The demand for immediate action is lower than for the other given challenges.

The identification of objects and the discrimination between e.g. anchors, civil scrap metal, fishing gear, rocks and munition objects is still challenging. The reduction of false target points and the more efficient identification of real munition objects would significantly decrease removal costs.

To increase our knowledge about the real munition contamination in dumping areas it should be considered to also use government ships designed for hydrographic surveys, whenever capacities are available. Comprehensive mapping of dumping areas is important for a well-informed prioritization of areas that should be cleared first (see section 6).

LINKS

→ *Kampmeier et al. 2020: Munitionserkundung in der Kolberger Heide*

→ *Kampmeier et al. 2021: Autonome und semi-automatisierte Kampfmitteldetektion*

6 MUNITION CLEARANCE TECHNOLOGIES

Only specialized organisations and companies have the capability to remove munition from the complex and dynamic marine environment. In German coastal waters, federal EOD squads are responsible. In addition, a few private companies exist in Germany – a rather unique industry in global context (see section 10 – Economic potential), as the military is solely responsible for munition clearance in most other countries. The strength of the private economy drives innovation in this sector. In Germany, most detected munition objects are removed and destroyed. Only a small number of items unsafe to handle are detonated on site. This type of in-situ detonation is much more common in other countries. Intentional detonations in the environment should be avoided, as detonations have negative effects on marine animals. In particular, marine mammals such as the protected harbour porpoise are impacted directly through the strong pressure wave. Additionally, toxic explosive remains can be distributed into the environment.

The CONMAR project develops concepts to recommend where and under which circumstances clearance of a dumping area should start. To achieve a solid prioritization, data that are often stored in data silos need to be made accessible. Such data are typically stored at many different federal and governmental institutions, and should be linked via a federated data management approach.

CHALLENGES AND SOLUTIONS

Underwater munition clearance can be performed by using different types of technologies and methods such as divers, remotely operated vehicles (ROVs), or multi-tools attached to excavators or crawlers. To clear munition dumping areas, the clearance efficiency must be improved while keeping the risk for humans at a minimum. Thus, the focus should be on remotely operated or autonomously operating devices, which can stay much longer in the water, move heavier objects, and can work during more difficult weather conditions than divers. In the German Baltic Sea, removal of unfused, small-calibre munition found in boxes in Lübeck Bay can start immediately. In parallel, more efficient methods and techniques for munition destruction should be developed.

Continuous monitoring of different operational steps is important to ensure the safety of involved personal, as well as to avoid environmental contamination by establishing an early warning system with a response action plan.

LINKS

→ *Frey et al. 2019: Qualitätsleitfaden Offshore-Kampfmittelbeseitigung*

→ *Siebert et al. 2020: Untersuchung von Schweinswalen*

7 MUNITION DISPOSAL APPROACHES

Munition disposal in Germany is executed at a number of institutions, the most important being the GEKA GmbH in Munster, which is located far from the coast. The capacities of all existing disposal sites are currently exceeded, and any large scale removal of marine munition would require interim storage sites on land. To avoid this, plans exist to destroy munition directly at sea. The needed technological sub-systems do exist but they have not yet been integrated into a working solution. There are plans to push such a development. Whether disposal at sea or at a dedicated area directly on the coast (or both approaches at the same time) is safer and easier/quicker to achieve has not yet been investigated in detail.

CHALLENGES AND SOLUTIONS

A disposal infrastructure should be established soon and close to one defined munition dumping area. The disposal of marine munition should be undertaken at sea or close to shore using infrastructure that is easy to re-locate. The needed technology already exists in large part (see section 10 Economic potential) and could be used on such disposal platforms. Government-owned GEKA GmbH should have a leading role in the development, construction and operation of such infrastructure. Discussions and cooperation have already started between the EOD and ship-building industries on development of concepts for such platforms.

LINKS

→ *Abbondanzieri et al. 2018: Kurzeinführung zum Projekt RoBEMM*

→ *Frey & Greinert 2020: Wie weiter mit den Kampfmittelaltlasten im Meer?*

8 NATIONAL DIMENSION – ACTORS AND RESPONSIBILITIES

The issue of munition in the sea affects a large number of public and private actors. At the federal level, it touches on areas of responsibility of the BMU, BMWK, BMBF, BMVg, BMDV and BMEL and their respective agencies. At the state level of each of the five coastal federal states, there are the ministries of the environment and of the interior, the latter represented by the state EOD squads. In addition, there are dedicated private specialist companies for the individual phases of explosive ordnance clearance – historical investigation, technical investigation, clearance and destruction. Furthermore, numerous relevant actors represent the interests of the environment.

In Germany, a multitude of relevant laws, regulations and legal frameworks exists for management of underwater munition. This is a consequence of the international, national and federal legal division of geographic areas at sea as well as the water-land transition which cannot be easily resolved.

CHALLENGES AND SOLUTIONS

Research institutes come together in project consortia and private companies do so in company networks. For many years, cooperation among authorities took place in the BLANO Expert Group on Munition in the Sea. In the past, impulses from environmental associations, participating in the expert group, pushed funding of scientific research. It is recommended that the process of solving the problem of munition in the sea be accompanied by a council of experts, which may include DAM members.

LINKS

→ *BLANO Expertenkreis „Munition im Meer" 2021: Aktuelle Gesamtbewertung*

9 INTERNATIONAL DIMENSIONS

There are many formats for international cooperation on munition in the seas (e.g. in JPI Oceans, HELCOM, BSCP or NATO). The munition is a global challenge, which opens up a multitude of opportunities to approach the issue. Germany's top-level research and its innovative companies should play a central role here.

The international reputation of Germany offers potential sales opportunities for technical developments. The successful clearance of a munition dumping area will be an unprecedented proof-of-concept, and will establish a starting point for international cooperation to clear marine munition.

CHALLENGES AND SOLUTIONS

Activity in international working groups is undertaken by experts as a pro bono activity. The CONMAR consortium has formed as an informal coordination body for German scientific organisations. In Germany, official concerns are often dealt with by representatives of the BLANO Marine Munitions Expert Group. Support for the coordination, including the funding of travel, is provided by the institutions themselves.

LINKS

→ *Expertengruppe HELCOM SUBMERGED*

→ *JPI Ocean Joint Action Munitions in the Sea*

→ *Stein 2021: Bericht an die Ostseeparlamentarierkonferenz*

10 ECONOMIC POTENTIAL

In most countries, the handling of marine munition is the responsibility of the navy. Germany is an exception to this rule, with a unique commercial EOD sector. The entire procedure from munition surveys to recovery can – with the support of the EOD services of the federal states – almost entirely be undertaken by the commercial sector. Only the final treatment of munition and its fuses is usually carried out by the governmental partner institutions.

In the past, innovation in this sector was driven to a large extent by the construction of offshore wind turbines. The ambitious expansion targets for offshore wind therefore already offer interesting prospects for companies in this sector. In addition, the politically announced entry into large-scale explosive ordnance disposal increases growth opportunities and can thus trigger a noticeable surge in innovation. Furthermore, competition among companies leads to continuous reduction in costs and an increase in efficiency. In recent years, the developments in the areas of sensor technology, data evaluation and robotic systems illustrate the high innovation potential. This offers German companies the opportunity to further develop high-tech solutions that create jobs and add value in Germany that can also serve international markets.

CHALLENGES AND SOLUTIONS

While incident-related munition clearance (e.g. in the context of offshore development) is initiated by a large number of clients, preventive clearance of highly contaminated areas has not yet started. Since there is no other incentive in the private sector to clear the dumping areas, the public sector must provide the necessary funds for the removal and disposal for many years. The German commercial EOD industry has the necessary skills and technologies to take on this task. However, reliable financial commitments are needed to initiate investments in the private sector. In addition, close cooperation between applied research, technological development and the public sector is required. Detailed explanations of the state of the art and concrete recommendations for actions to establish and promote the full value chain potential can be found in a position paper of the Gesellschaft für Maritime Technik e.V.

LINKS

→ *Netzwerk MUNITECT*

→ *Positionspapier Gesellschaft für Maritime Technik e.V. (GMT)*

→ *Ocean Technology Campus Rostock*

→ *Frey & Greinert 2021: Bomben am Meeresgrund – Der Umgang mit den Kriegsaltlasten in der deutschen Ostsee*

11 CURRENT RESEARCH PROJECTS

In addition to the research projects that were mentioned throughout the text, the following list offers a more comprehensive compilation of ongoing and coming research and development projects in Germany:

- BASTA – Automatisierung und Effizienzsteigerung bei der Munitionssuche (here)
- ExPloTecT – Chemische Echtzeit-Messung von sprengstofftypischen Verbindungen (here)
- ProBaNNT – Risikobewertung und 3D-Objektrekonstruktion bei der Kampfmittelbeseitigung (here)
- NorthSeaWrecks – Untersuchung von munitionsbelasteten Wracks in der Nordsee (here)
- Zusätzlich existieren weitere toxikologische Auftragsarbeiten die vom Land SH oder dem Bund finanziert werden (here)
- TOxAR: Arbeitsschutzsystem für Taucher unter Wasser bei der Bergung von Munitionsaltlasten (here)
- EXTENSE: Entwicklung eines Messsystems zur Detektion und Ortung von Objekten (Kabel, Munition und Tiefseebergbau) in Sedimenten (here)
- UnLowDet: Laserinduzierte Unterwasser-Low-Order-Detonation zur effizienten Entschärfung von Kampfmitteln im Meer (here)
- Marispace-X: Digitaler Datenraum für Munition im Meer auf Grundlage der europäischen Dateninfrastruktur Gaia-X (here)

On top of that, several projects which are either explicitly dedicated to marine munition or are associated to this topic have been successfully submitted and are about to start in 2023.

- BorDEx – Entwicklung eines beschleunigten und ortsveränderlichen Verfahrens zur Munitionsvernichtung (submitted to BMWK)
- IRAV – Entwicklung einer Plattform zur Industrielle Räumung von Altlasten in Verklappungsgebieten (funded by BMWK)
- VAMOS – Verbesserte Autonome Meeresboden Observations-Systeme (funded by BMBF)
- ValidITy – Validation of Intelligent Terrain and Feature Recognition Methods for Hydrographic Data (funded by Helmholtz Validation Projects)
- SAM – Smart AUV-based Magnetics (funded by Helmholtz Validation Projects)

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