CLEARANCE OF CONTAMINATED SITES IN THE SEA

Scientific and technical explanations on the current level of industrial competence on the subject of contaminated sites in the sea
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Authors:
The Munitect network is an association of companies and research institutes that promote the development of economically effective detection systems for unexploded ordnance (UXO) underwater. The cooperation bundles the skills and diversity of experience from the various branches of the network partners and increases the exchange of experience.

The dumped munitions and unexploded ordnance (UXO) that lie on the seabed in the North and Baltic Seas pose an increasing danger to humans and the environment. Numerous studies and projects have shown that salvage of the weapons is not only essential, but also technically feasible.
Regarding the costs of a salvage, they are high, but they can be paid for. Research in the Kolberger Heide munitions dumping site near Kiel can serve as a guideline: In recent years, there has been an intensive investigation into how many ordnance there are on the seabed and what the costs of a salvage would be. An initial cautious estimate showed that it should be possible to vacate this area in less than ten years - for a total of less than 20 million euros per year.

Network management
Prof. Uwe Freiherr von Lukas
Dr.-Ing. Kristine Bauer

Munitect
c/o Fraunhofer IGD
Joachim-Jungius-Straße 11
18059 Rostock
Deutschland

Tel. +49 381 4024 408
Fax +49 381 4024 199
info@munitect.de
www.munitect.de/en/home

1. Key messages on the active clearance of contaminated sites

1. The clearing of dumping areas is now feasible and affordable. Estimates using the example of the Kolberger Heide near Kiel (approx. 18,000 major ordnance) calculate processing in less than 10 years for less than € 20 million annually.
2. Cost reduction potentials with simultaneous security in processing can be represented in the expert combination of already existing robot-based technologies and adaptation developments from other fields of application.
3. Research programs are a very helpful and effective means of developing technologies in this area - but they are not given the necessary attention from an industrial point of view if no industrial utilization perspective can be given.
4. The German industry with the focus on unexploded ordnance in the sea, initially represented by the network Munitect, sees itself able to form a consortium that, with the participation of local industrial partners in the states bordering the Baltic Sea, can run the remediation of dumping sites. This consortium combines the necessary skills of diving, hydrographic surveys, ordnance clearance, technology companies and application research. Corresponding partnerships in this field of application have existed for years between companies and institutes from the Baltic Sea region in individual constellations.
5. Large-scale projects in the maritime sector have been successfully carried out by these civilian companies in the past 10 years. Up to 10,000 suspicious anomalies were recovered and finally eliminated. Such large projects were e.g. the clearing of offshore cable routes and wind farms, the LNG port in Swinoujscie, the deepening of the Elbe Hamburg and the ammunition dumping site Minsener Oog.
6. The partners commit to deal calmly with the topic without harming tourism and fishing.
7. Large industrial companies from Germany are able to economically secure such projects and provide technologies that were previously only accessible to military users.
8. A competent and economically stable consortium is created in association with medium-sized experts on the subject of ordnance clearance, which is up to the task of generation[1].
9. Germany as a technology location sees environmental technologies as an opportunity for economic development and, through technology transfer, ensures sustainable and ecological economic development throughout the Baltic Sea region.
10. An industry- and practice-related connection between stakeholders and contract awarding is imperative in order to know the rapidly changing industrial state of the art. The pure research level cannot bring this focus.
    The Fraunhofer IGD, with its order for industry-related technology transfer and monitoring, is a strategically excellent partner, in particular due to the underwater test field with ammunition garden in the future Ocean Technology Campus and the many years of preparatory work by looking after the industrial Munitect network. The Ocean Technology Campus [2] continues to be international and will become a hub for permanent cooperation.

[1] The 'National Information Center for Chemical Warfare Agents' initiated by Munitect, nick-ev.com, is also supporting by experts

[2] https://www.igd.fraunhofer.de/sites/default/files/media/projekte/digital_ocean_lab_english.mp4

2. State of the art

The main burden of today's salvage work is done by ROVs (Remotely Operated Vehicles). The surveys for ordnance are mainly carried out today through the use of multichannel underwater magnetometer systems. Initially, these were used in purely towed or mast-guided versions. Today ROTV '(Remotely Operated Towed Vehicles) are the most efficient means of quickly examining large areas.

Left: ROTV with multichannel magnetometer systems of Patzold Köbcke Engineers GmbH from Buchholz i.d. Nordheide; Right: AUV-Systems of ATLAS ELEKTRONIK GmbH from Bremen

The geophysical data collected from magnetometer surveys are usually additionally verified by multi-beam, side-scan sonar and sub-bottom profiler data or supported for evaluation.

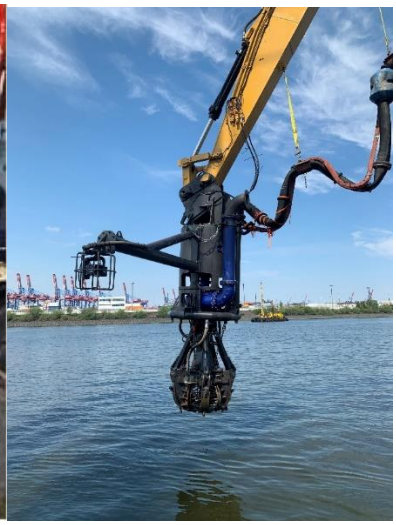
Military users are increasingly using AUVs (autonomous underwater vehicles) for the detection of sea mines. As a result of the promotion of marine technology in recent years, various European manufacturers have been able to make equivalent alternatives to products classified as weapon systems by US manufacturers available to civilian users. These systems already successfully and efficiently perform surveying tasks in the field of condition monitoring of underwater structures such as pipelines or submarine cables.

Software tools such as Oasis Montaij and Quinsy are used to extract possible UXOs from the amount of data collected. If the weapons are on the surface of the seabed the identification is relatively accurate, similar to military mine hunting. The situation is different with weapons sunk into the seabed or covered with sediment. Reliable identification and above all the differentiation from other metallic objects, e.g. anchors, anchor chains, civilian scrap, steel cables, fishing equipment etc. is not yet available on the market. However, developments in recent years indicate that this will change in the near future.

Another problem is the frequent presence of stones with ferromagnetic inclusions. A large number of stones of this type are modeled as a possible weapon in the modeling of the common software packages and thus further increase the number of possible anomalies suspected of being a weapon.

A promising way to circumvent this is the use of electromagnetic pulse induction detectors. Here, a magnetic field is generated and measured in the target object, which must consist of inductive material. The advantage is that as well no ferrous metals are measured, i.e. non magnetic mines cannot be detected, and stones with magnetic inclusions play no further role.

In the exploration of so-called "boulder", i.e. large stones sunk into the seabed, which are a hindrance for example when ramming monopiles of wind turbines, significant leaps in development have been recorded in recent years. By using synthetic aperture multi-channel seismic systems, it is now possible to detect and characterize boulders in the sediment up to 50 m deep with sufficient resolution. An adaptation to the lower penetration depths for UXO detection enables a further increase in the resolution of such systems. Some ongoing projects aim to be able to detect sedimented UXOs even on large scale.

Left: Multi-channel seismic system from Fraunhofer IWES for boulder detection. The illustration on the right shows such a system from the Baltic Diving and Recovery Company Rostock GmbH

One of the most important new developments for the salvage of ordnance in shallow water depths are the so-called multi tools. These are usually powerful excavator pumps (DOB), which are combined with grippers, underwater magnets, EM survey coils and imaging sonar systems and are mounted on the arm of a hydraulic excavator.

In order to be able to use such systems in deeper water, they are already installed on powerful backhoe dredgers today. Water depths of 28m can thus be reached, but at very high salvage costs, since the number of such powerful ships is limited and due to their size they are a very cost-intensive platform.
The key is therefore to reduce the anomalies to be recovered or to differentiate scrap from real weapons. There have also recently been promising first attempts to use EM-based classification systems under water.

The figure shows an ROV-based classification system, which is able to reduce the number of objects worthy of recovery to 20-25%.

3. Disposal and processing

Imagine the recovery of millions of tons of weapons from the Baltic Sea and their disposal on land. In addition to the logistical challenges and the simply lack of possibilities to destroy such quantities on land today, the transportation of chemical warfare agents in particular poses a considerable risk to the population.

The multitude of local regulations and boundary conditions can be reported comprehensively, owing to the international, national and federal division of areas as well as the water-land problem. The *Quality Guideline for Offshore Ordnance Disposal* was developed with Munitect partners and represents a summary and structuring of the current qualitatively necessary parameters in the overall process and should form the basis for further requirements discussions.

The solution for this lies in the development of robotic, remote-controlled systems for the recovery and destruction of weapons. Efficient disposal on site can only be carried out by the construction of sea-based and mobile destruction facilities.

The purely technical possibilities for this already exist and, according to the authors, can be implemented sea-based on board specially designed destruction platforms.

In the past, the only demonstration of a sea-based extermination facility in the world was held by the Japanese company Kobe Steel Ltd., which developed a vacuum extermination facility for the removal of chemical warfare agents on a floating platform many years ago.

Left: The picture shows the heart of the system, the DAVINCH ® (Detonation of Ammunition in a Vacuum Integrated Chamber) vacuum furnace; Right: The *SDC 1500 der Dynasafe based in Stockholm – Schweden*

First investigations of industrial companies in the areas of excavator and crane systems, warfare agents and naval shipbuilding have already taken place. A point that is not forced but worth mentioning in this context is the fact that companies with the necessary expertise can be found within the countries bordering the Baltic Sea.

By mutual agreement between these companies, the construction of a corresponding destruction facility at sea is considered feasible.

4. Data management and analysis

The management and analysis of data play an essential role in understanding, planning measures and monitoring. Developments in the areas of artificial intelligence and big data in particular create numerous opportunities in the area of ammunition in the sea. Including these technologies, the development of an intelligent and cross-border system is therefore of central importance for the networking of business, science, authorities and NGOs in the field of munitions in the sea.

The following data are relevant for these questions:

- Historical data (documents / maps / reports etc.)
- Physical measurement data: multibeam, side scan sonar, geomagnetics, electromagnetics, sub-bottom profiler
- Measurements of explosive-typical compounds in different matrices (sediments, open water, organisms)
- Environmental parameters in the area and surroundings of dumping sites (flow speed, salinity, etc.)
- Modelling, for example, of flags of propagation from STVs

These different types of complex data must be combined in order to record and evaluate the extent of the ammunition load. Almost all of this data relevant to the topic has a spatial context. Thanks to the possibilities for recording, visualization and analysis that current technologies offer, this information can be made available in a much simpler way and used for the subject of ammunition in the sea.

5. International activities

There are a number of international activities in which partners from the Munitect consortium are also involved. So far, however, these have mainly focused on the research sector. These include, for example:

DAIMON I + II

DAIMON carries out a risk assessment using artificial intelligence for marine areas contaminated with chemical and conventional warfare agents. Numerous measurement data (fish, sediments, etc.) are brought together in the central database of the international ammunition register AMUCAD and made available by this data in combination with the risk assessment. In addition, management concepts based on scientific knowledge are being developed for areas in the Baltic Sea and Skagerrak contaminated with munitions.

BASTA

BASTA aims to advance the current approaches in the detection of ammunition both locally and on a larger scale. Performing data analysis of large amounts of data using artificial intelligence will lead to new approaches in the detection and identification of ammunition. The data collected are administered and analyzed in the international ammunition register AMUCAD.

NorthSeaWrecks

The focus is on shipwrecks that sank with ammunition and oil during the two world wars. This dangerous cargo poses a threat to humans, the environment and blue growth operations. The project will provide a comprehensive methodology for assessing, investigating and describing wreck sites, including sensitive aspects of cultural heritage, and will be integrated into the AMUCAD international ammunition register.

EXPLOTECT

As part of the project, a prototype system for the ship-side, real-time detection of dissolved explosive compounds and chemical warfare agents in sea water is being developed.

JPIOcean

The network also supports the establishment of joint activities in the JPI Oceans working group to support interdisciplinary research in the field of contaminated sites across Europe.