

Field-Based Risk Assessment of Sea-Dumped Munitions: Insights from the ALKOR 622 Monitoring Expedition in the Baltic Sea

by Bhumika Sharma

Dr. Aaron Beck and his team from the GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, invited Prof. Tracey Temple and her team from Cranfield University, Shrivenham, to visit the research vessel ALKOR 622. The objective was to exchange knowledge and technical expertise on the monitoring and risk assessment of World War-era sea-dumped munitions. I joined the Centre for Defence & Security, Cranfield University, Shrivenham in October 2023 to pursue PhD under the supervision of Prof. Tracey Temple and Prof. Frederic Coulon. My research focuses on “Scientific Advancements in the Development of Risk Assessment for the Clearance of Dumped Munitions”. I had the privilege of participating in the expedition aboard ALKOR 622 on October 19, 2024, departing from Neustadt, Holstein in Germany.

Context of sea dumped munitions post world wars

Post-World Wars, unused war materials were routinely dumped in the seas all around the world. Currently, there are hundred thousand tons of munitions in the European waters alone (1-3). The dumping continued until legislation, namely the London Conventions, 1972 on the Prevention of Marine Pollution came into force. There are no comprehensive records of these dumped munitions but based on some recovered data there are more than 1.6 million metric tons of conventional munitions in the German North Sea and the Baltic Sea. These munitions are decreasing in stability and becoming more sensitive with age (4-5). There are reports of several spontaneous detonations of these conventional munitions. Apart from explosions creating high levels of noise and vibration, there is also a high risk of toxicity due to the spread of carcinogenic and mutagenic explosive compounds that are dispersed into the oceans and sea. This creates an urgent need to monitor conventional munitions resting on the seabed, as they potentially leach harmful substances into the surrounding environment.

The Alkor 622 capability – Identification & Detection of munition hotspots

The ALKOR 622, a 55-meter research vessel, operates mainly in the North and Baltic Seas, conducting expeditions up to 21 days long (Figure 1). Equipped with advanced Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs), the vessel facilitates high-resolution seafloor mapping, sediment and water sampling, and in-situ contamination assessment.



Figure 1: ALKOR 622 research vessel in the Baltic Sea near Neustadt port, Holstein, Germany

The equipment on-board the vessel enables detection and identification of munition hotspots using bespoke Autonomous Underwater Vehicle (AUV) & a Remotely Operated Vehicle (ROV) depicted in Figure 2. The instruments are deployed in the water using Crane and are equipped with conductivity, depth, temperature, oxygen level and salinity sensors.

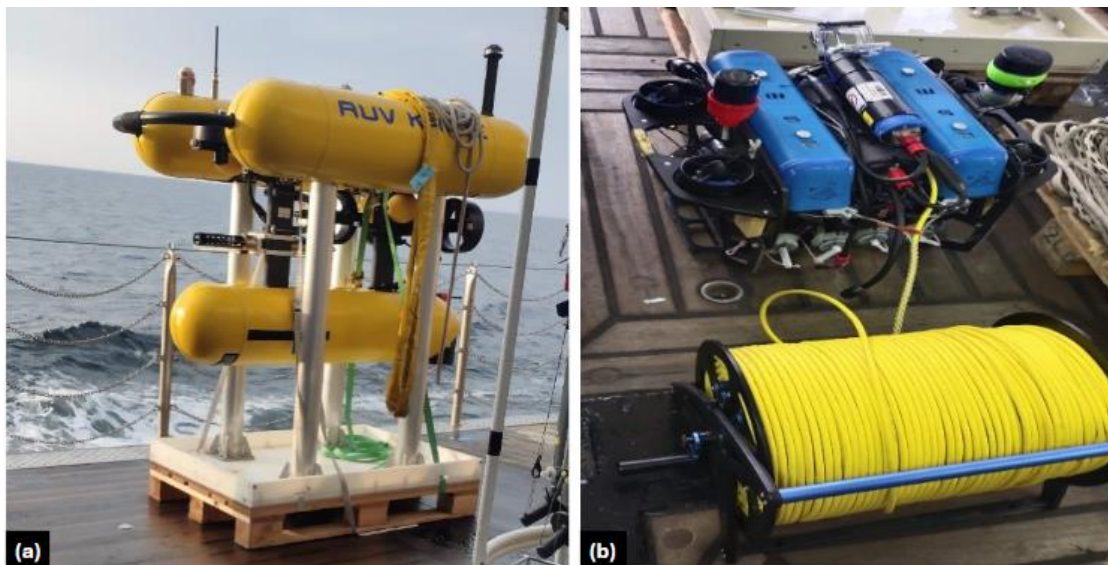


Figure 2: Detection equipment of munition hotspots (a) Autonomous Underwater Vehicle (AUV) (b) Remotely Operated Vehicle (ROV)

AUV is a programmed instrument that works on set instructions and helps with the mapping of seafloor and sub-seafloor. For example, this AUV was programmed to move along a

specific area in a pattern as shown below and clicks pictures of the seabed and then creates a 3D photo mosaic using these pictures to detect the munition piles. Figure 3 (a) shows the photo mosaic and mapping of munition piles. After the mapping ROV is sent to the set location to see the conditions of these munitions as shown in Figure 3 (b) and hotspot marking on the map is represented in Figure 3 (c). ROV is always attached to the ship using strings and remotely operated. It can also be used for other purposes such as sampling, to implant devices such as acoustic signal devices to measure water current, pulling out samplers, etc.

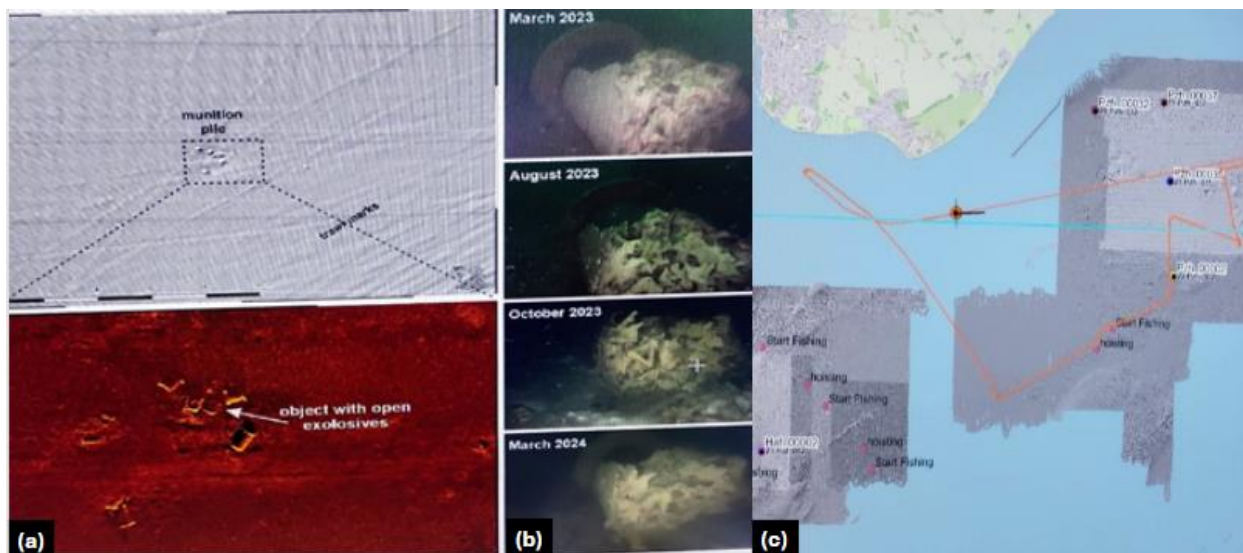


Figure 3: (a) Mapping of seafloor using AUV (b) monitoring the munition conditions using ROV (c) marking the munition hotspots on the map

Sampling: Water & Sediments

Following the identification of munition hotspots, the next step is environmental sampling. During the Alkor 622 cruise, water and sediment samples were collected to assess the release of explosive compounds from dumped munitions. Water sampling was conducted using devices equipped with CTD (Conductivity, Temperature, and Depth) sensors, enabling precise sampling at target depths while simultaneously recording real-time data via Dship Jens software. Both surface and deep-water samples were collected to develop a vertical water profile. CTD parameters were continuously logged along the trajectory of the sampler, AUV, or ROV, with downward casts preferred to minimize sample contamination during retrieval. A dedicated file can also be generated for each sampling bottle, recording associated environmental parameters. Collected data are processed and converted into usable formats using OceanView software. Two sampling methods were employed: large-volume samplers (10 L) as shown in Figure 4(a), and ROV-based samplers (1 L capacity).



Figure 4: (a) Water Sampler (b) Sediment Sampler

Sediment sampling was done using sediment grabber attached to a pulley system as shown in Figure 4 (b). The whole setup was washed with clean water before and after sampling. To the identified hotspots the grabber was deployed. It also consists of a camera to monitor the activities of the grabber and to avoid any munition being grabbed to avoid the risk of accidental explosion. The contents of the grabber were emptied in a clean plastic container, plastic apparatus is preferred to avoid any reaction with explosives. Two types of samples were collected (a) 3 sub-grab samples were collected using a big spatula (100-150 g) in zip locks for the study of physical properties of sediments including grain size and total organic carbon. (b) the samples were filtered using a 0.5 mm sieve and collected in a labelled plastic container (500 mL) using a plastic funnel for the toxicity studies of micro-organisms. The collected samples are stored at -22°C before analysis. Samples were thawed and kept to a constant room temperature before analysis. The next step is to extract explosives from these samples to avoid any interference that may affect the results.

Extraction of explosives from water and sediment samples

The extraction of explosive residues from environmental samples was carried out using two distinct approaches:

(i) Manual extraction: in this method, sample pouches were suspended and connected sequentially to a glass fiber filter and a Solid Phase Extraction (SPE) cartridge, as illustrated in Figure 5. Relying on gravity, the sample was allowed to pass through the filter and cartridge, enabling the retention of explosive compounds within the SPE material. These retained analytes were subsequently eluted using a water/acetonitrile mixture, preparing them for further analysis.

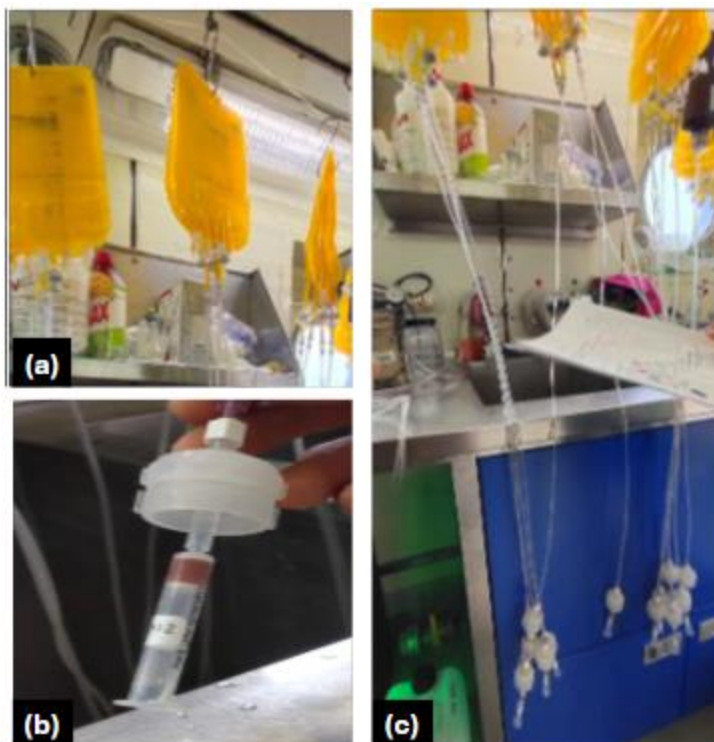


Figure 5: Extraction process involving (a) Sampling pouches (b) SPE Cartridge (c) The complete extraction setup

(ii) Automated extraction: This approach utilized a compact, integrated system combining SPE with HPLC and UV-MS detection (SPE_HPLC_UV_MS), as shown in Figure 6. Specifically designed for field applications, this portable setup streamlines the extraction of explosives from complex matrices such as sediments and water. Following extraction, High Performance Liquid Chromatography (HPLC) is employed to separate the explosive compounds for subsequent quantification and characterisation.



Figure 6: SPE-HPLC-UV-MS Integrated System

Analysis of explosives

High Performance Liquid Chromatography (HPLC) was employed to separate potential explosive compounds based on their differential partitioning between a reverse-phase stationary column and an organic mobile phase. Following chromatographic separation, analytes were detected using either an Ultraviolet (UV) detector or a Mass Spectrometer (MS). The UV detector operates by measuring the absorbance of specific wavelengths of light by the analytes, while the MS provides compound-specific identification based on their mass-to-charge (m/z) ratios.

Future Insights

One of the major challenges encountered by scientists aboard the ALKOR 622 research vessel was the highly dynamic marine environment—characterized by strong tides, variable currents, and high hydrostatic pressure. Additionally, the collected samples generally contained only trace levels of explosive residues, except for those obtained in close proximity to the dumped munitions. Manual extraction from large sample volumes (1 L or 10

L) was therefore labour-intensive and time-consuming. However, the use of an integrated, portable analytical system—referred to by the scientists as a “lab in a box”—proved highly effective. This system delivered accurate and specific results and was capable of analysing key explosives such as 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and their derivatives including 1,3-dinitrobenzene (DNB) and 4-amino-2,6-dinitrotoluene (ADNT), with each analysis completed in 15–20 minutes. As illustrated in Figure 6, the instruments were secured to stabilizing poles to minimize motion, though the need for more robust stabilization solutions in such conditions remains evident.

My participation in the ALKOR 622 expedition was an invaluable experience. Interacting with experts focused on monitoring and analysing WWII-era munitions dumped at sea provided direct insights aligned with my PhD research on the risk assessment and remediation of underwater munitions. This engagement deepened my understanding of the multifaceted risks posed by aging munitions—including structural degradation, spontaneous detonations, and leaching of toxic compounds—within a challenging oceanographic context. Observing ALKOR 622’s advanced technologies for detecting munition hotspots offered a practical perspective on contamination assessment and risk mitigation strategies. These field-based insights serve as a vital complement to my laboratory research on corrosion-induced leakage and the environmental fate of explosive residues in marine ecosystems.

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