Unticking ticking bombs

CONcepts for conventional MArine Munition Remediation in the German North and Baltic Sea (CONMAR)

U. Gräwe, E. Chrysagi, H. Burchard, *Leibniz Institut for Baltic Sea Reserach*

In Short

- Investigation of transport pattern of dissolved munition compounds
- Identification of regions with maximum or chronic exposure
- Develop and test potential clearance and remediation strategies

Abstract CONMAR aims to integrate existing and new data-sets on historic marine munitions, combine expertise and knowledge of German marine science organisations, governmental bodies and private sector, advance our scientific understanding of the role, fate and impacts of marine munition in the environment, and provide policy solutions for monitoring and remediation actions in consultation with stakeholders. This work is funded though the BMBF project CONMAR within the BMBF - DAM-Forschungsmissionen Schutz und Nutzen call, running from 2021 - 2024.

Motivation Coastal waters are impacted globally by relic dumped munitions resulting from the two World Wars (WWI and WWII). The German portions of the North Sea and Baltic Sea alone contain some 1.6 million metric tons of munitions. The distribution and condition of munitions in German waters are not well known. In addition to the explosion and security risk, these munitions contain cytotoxic, genotoxic, and carcinogenic chemicals associated with conventional explosives, chemical warfare agents, and munition structural components. There is growing interest in remediating undersea munitions due to ecological and human health risks and the hazards associated with dredging and increasing development of offshore infrastructure associated with aquaculture, wind farms, cables, and oil or gas pipelines, and increasing ship traffic in general.

The issue of munitions in German waters and the German exclusive economic zone (EEZ) is insufficiently and ineffectively governed in multiple ways. Responsibilities for remediation and hazard control of munition is distributed variously among the armed forces for the EEZ and the bomb disposal teams of the five coastal federal states. Furthermore, there is a complete absence of a structured decision-making process that guides the management of the 50 munition dump sites and otherwise munition contaminated areas in German waters (Fig. 1).

Monitoring activities would provide the base for decision making and subsequent actions. Numerous organisations have started to bundle competencies. The Ministry of the Environment of the state of Schleswig-Holstein (MELUND) is facilitating formal exchange between relevant authorities via an expert group on munitions in the sea and informal exchange with industry players, NGOs and the public via research projects and conferences. The central reporting unit for munitions in the sea, integrated in the joint centre of the water police of the coastal federal states (Maritimes Sicherheitszentrum), collects information on all munition encounters in German waters.

The widespread presence of munitions on the Baltic and North Sea seafloor makes it challenging to link specific munition compounds (MC) sources to plumes of dissolved MCs in the water column. Elevated concentrations were observed in the distant Arkona basin during the UDEMM project (Greinert, 2019) and the wide dispersion of MCs on local scales implies long-range transport of MCs. This must occur on relatively short time scales before loss by microbial or abiotic degradation or sorption and sedimentation with particles occur. Oceanographic modelling helps identify and prioritise pollutant sources for remediation to reduce the primary inputs. UDEMM results indicated that transport of MCs occurs primarily within the dissolved phase, with less than 1% of the total MC concentration associated with suspended particulate matter. Oceanographic modelling of TNT release by dissolution and degradation by microbes produces trends that reasonably match field data. This suggests that the spatial distribution of MC can be largely predicted by these two controls (Greinert, 2019).

However, nothing is known about the effect of these controls on the dissolution of other primary explosives in German waters, including RDX and DNB. Seasonality and depth distributions of MCs are less well predicted by existing models, suggesting additional processes that must be constrained. Seasonal effects on dissolution of solid explosives may derive from temperature (higher in summer), mixing (higher in winter) or enhancement by organic matter (e.g. surfactants; higher in summer). Alternatively,

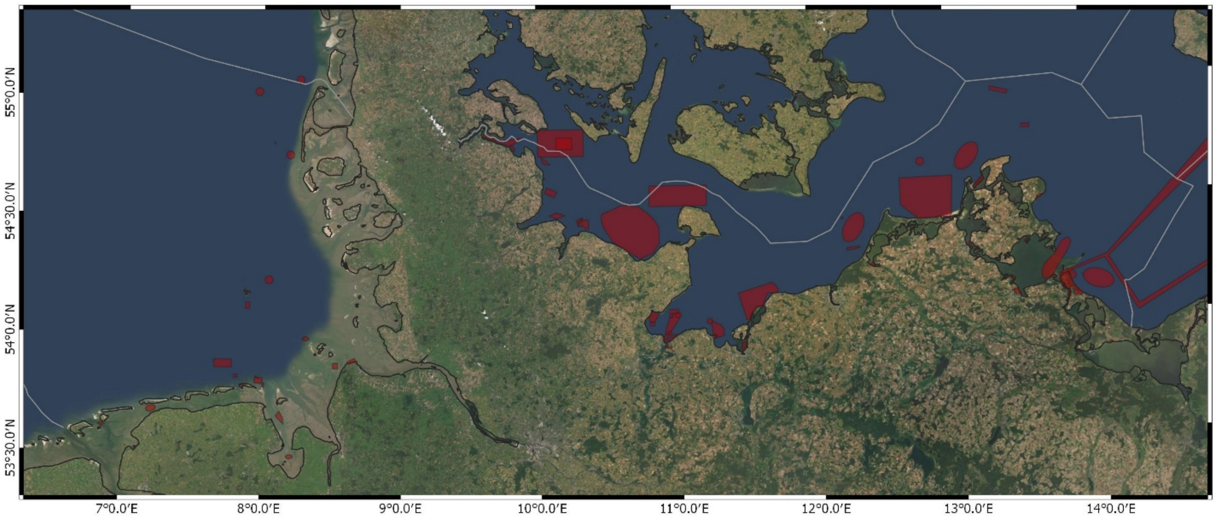

Figure 1: *Map showing munition dump sites and munition contaminated areas in the German North and Baltic Sea (data source EGEOS GmbH).*

seasonality may result from removal by direct microbial degradation (higher in summer), or effects of oxygen levels and H2S on TNT degradation (potentially lower under anoxic conditions). These factors have so far not being considered in any modelling approach related to marine munition.

No detailed investigations of the potential additional impact of climate change on sea-dumped munition have been undertaken. The impact of temperature and increased storm activity on dissolution rates, abrasion and transport, or TNT's transformation into its metabolites is still largely unknown. From an environmental perspective, the Baltic Sea shows the highest warming rates worldwide (Belkin, 2009; Stramska and Bialogrodzka 2015) and since temperature is very important for the dissolution of explosive compounds (TNT and others), a warming climate will likely increase the TNT concentration in the vicinity of munition dump areas. The year 2018, with record-high water temperatures in the Baltic Sea (Naumann et al., 2018), revealed persistent thermal stratification as the second thread related to climate change. This decoupling of surface dynamics and near bottom dynamics will enrich dissolved TNT in near-bottom waters, resulting in elevated TNT levels. In parallel, the vertical stratification will have an impact on the O2/H2S dynamics. Until now, it is unclear whether H2S will suppress or enhance the dissolution rates of explosive compounds and additional to temperature other properties might regionally increase TNT release. Assuming a future increase in frequency and strength of extreme weather events as storms, it can be postulated that an increase in loads and shear stresses acting on marine munition objects and open TNT will increase. This will result in an enhanced distribution of particulate and dissolved MCs with consequences for the environment

The Modelling A multi-nested model system covering the entire North Sea and Baltic Sea will be established with regional nests into the German Bight and western Baltic Sea. This will allow a seamless tracking of dissolved MCs across all scales from 2km to 50m (Gräwe et al. 2016). Coupling a spectral wave model (WavewatchIII, Toleman 1991) will likely increase dissolutions rates in the presence of wind waves. Dissolution of TNT metabolites and other MCs (RDX, DNB) will be parameterised using dissolution rates collected in lab experiments. Modified equations for particle erosion and transport will be updated, and an additional source term for the release of MCs from buried munition will be added. The ocean model of choice will be the General Estuarine Transport Model (GETM, www.getm.eu).

WWW

https://www.io-warnemuende.de

More Information

[1] https://getm.eu

[2] https://udemm.geomar.de/de

Project Partners

GEOMAR, AWI, GCF, Senckenberg, Thünen, UBA, UKSH, URO

Funding

BMBF - DAM-Forschungsmissionen Schutz und Nutzen call (# 03F0912D)