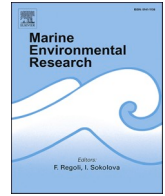




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Contaminated by war: A brief history of sea-dumping of munitions

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A B S T R A C T

Munitions introduced to the sea during military activities, including naval combat and mine warfare represent only a fraction of military material present in seas and oceans. Huge amounts of obsolete conventional munitions and chemical munitions were dumped to the sea until 1975, when London convention put a stop of sea dumping. Such munitions are a threat for maritime workers, but also for environment. Corroding shells release toxic degradation products to sediments and bottom water, and unlike other contaminants, they cannot be reduced by land measures. Only removal of source can reduce the contamination. Much work has been done in the last decade, and mechanisms of toxicity and bioaccumulation are being recognized, as well as transport and spreading mechanisms. The full assessment of the risk associated with munitions now depends on broad application of developed techniques.

Introduction of munitions into the seas started in the middle of the 19th century when breech-loading rifles and artillery able to shoot grenades with solid shells filled with propelling charges and explosives were developed. These new weapons were installed on the shores as well as aboard warships, and during exercises and war actions the first significant amounts of munitions entered marine waters. During World War I, naval mines were developed and applied to secure harbours, and later on, air bombs, torpedoes and depth charges followed and partly remained in the sea after the war. However, this type of contamination caused by direct war activities presents only a fraction of the environmental hazards caused by war materials currently at hand, with deliberate dumping being the main issue.

The principle of sea-dumping of unwanted materials is simple. In times of rapid development of new weapons and types of munitions and explosives, outdated and inoperative munitions needed to be disposed of. Submerging of the extensive ammunition stocks in seas was considered as an efficient and unproblematic solution in regard to security. Strict legal restrictions now prevail in most countries, including the London Convention, which has been in force since 1975. However, concerning the getting rid of the notorious chemical warfare agents (CWA) contained in various types of munitions and containers after World Wars I and II, the massive sea-dumping of these substances, which were designed to cause damage and death to humans, was carried out in perfect agreement by the Allies after WW II, simply because it could be done. From the late 1940's to early 1960's, hundreds of thousands of tonnes of CWA, consisting of substances such as the infamous mustard gas and exotic-sounding names such as Adamsite, Lewisite and Tabun,

were shipped to more-or-less suitable coastal and offshore areas of the seas in Europe and elsewhere for quick riddance; in fact so quick that, in numerous cases, *en route* partial discarding of the deadly cargo was reported and the scuttling of whole munition-carrying vessels was a common practice.

In addition, huge amounts of outdated conventional munitions containing highly toxic explosives such as TNT and RDX have found their way to the depths – and in many places not so deep either, being present even in coastal areas next to popular public beaches. The legacy of previous wars in the form of unexploded ordnances at the sea bottom, scattered over large areas or piled, are, also literally speaking, an environmental time bomb. As discovered recently by scientists from University of Kiel, a cloud of dissolved explosives is wafting through the entire German part of the western Baltic Sea, resulting in measurable body burdens in all investigated organisms that have been in contact with the munitions. These are the today's consequences resulting from the “Out of sight, out of mind” principle of our ancestors.

The environmental problem associated with the sea-dumping of unused CWA as well as the conventional munitions indeed used during the wars is only now emerging at an accelerating pace. This is due to the progressive corrosion of the munitions, bombs and containers filled with the notorious substances that is now starting to reach a point when they are leaking out in a serious way. In many countries this news has led to significant public concern, and requests for mitigation activities are spreading fast. So far most of the human victims of sea-dumped CWA have consisted of some unlucky fishermen exposed to the highly unwanted catch of lumps of mustard gas. However, also several incidents

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from affected and also poisoned seafood consumers were ascertained in the late 1940s and early 1950s related to cod roe and liver from specimens caught close to known dumping sites.

What about the marine environment then: the organisms, populations and communities, the living ecosystem? As said, the problem is just emerging and nothing quite drastic has been reported so far, although suspicions of the possible role of dumped war materials have been aired in cases of local ecological changes and damage. To put it straight: although never assessed in detail, there are probably more severe environmental challenges in our seas than dumped munitions. However, the fact that although the toxic substances have resided at the bottoms of the seas for well more than a half a century they are only now truly starting to be a problem due to the advanced corrosion state – so they can actually be categorized under “contaminants of emerging concern” (CEC), although this label has mainly been reserved for “new” substances showing regularly up in increasing quantities in environmental samples. Whatever the categorization, the toxic substances potentially leaking out from the dumped munitions add up to the bewildering mixture of contaminants present in the marine ecosystem. Essentially, there is uncertainty of how a wide-scale problem we are dealing with exactly and what would be the most cost-effective ways for mitigation in the different dumping areas. There are obvious research gaps that need to be filled to come up with viable solutions to the issue. However, one fact is already obvious now: contrary to other major environmental threats such as excessive nutrients, plastics and pharmaceuticals that can currently be controlled only by substantial onshore investments in water cleaning plants or changes in current production, consumption and disposal practices, the potential impact of dumped munitions can be reduced by each shell or container retrieved from the seafloor.

The Baltic Sea and the Skagerrak Strait are focal post-war munition dumping areas globally with an approximated amount of 50,000 and 190,000 tonnes of CWA containing munitions, respectively, in addition to largely unknown quantities of other war materials. The Baltic Sea is the world's second largest brackish waterbody and a unique ecosystem in many ways. In addition to its low salinity its main characteristics include shallowness (mean depth 55 m) and very poor water renewal, which occurs through a few narrow straits in the SW part of the basin. The human population of almost 90 million surrounding the basin is putting increasingly more pressure to the area; marine traffic and the emerging of new coastal and offshore activities and installations such as wind parks and oil and gas pipelines are growing fast, and issues related to the use of the seabed are more frequent than ever. Within the past 15 years, several EU funded international projects (MERCW, CHEMSEA, DAIMON and DAIMON 2) and NATO (MODUM) have targeted at dumped munitions in the Baltic Sea, focusing on their detection, distribution, environmental fate of the toxic substances and their ecological effects, risk assessment and mitigation strategies including decision support for end-users. Thus, a great deal of new information has been obtained about the characteristics and severity of the issue in different localities, but many questions remain unresolved, including the Big One: should they be removed or left untouched?

Taking the munitions up may pose technical risks that could cause even more harm to the environment, and in some cases, e.g., concerning

large, unexploded ordnances, is considered an unfeasible option applying the remediation techniques currently available. However, the vast majority of the munitions in the Baltic Sea are remains of dumping activities, not war leftovers. The stockpiled sea mines were dumped without detonators and can thus be retrieved and disposed of with newly-developed, emission-free remediation techniques. The same also holds for the millions of grenades, anti-aircraft and machine gun rounds partly dumped in shallow waters near the coasts. In joint ventures, scientists and the industry have already developed prototypes of equipment for munition remediation, ready to prove their abilities once policy-makers and authorities reach a consensus on the matter and flag their willingness to move on with this topic. Conclusively, it is mostly about decision-making now – but the sand in the hourglass is running, and faster towards the end.

This Virtual Special Issue of MERE consists of a collection of papers originating from recent projects focusing on dumped munitions in the Baltic Sea. It covers various aspects ranging from distribution of the munitions, concentrations of CWA and explosives in environmental matrices, and their toxicity and sub-lethal effects on local biota. In short, the research accomplished in these papers shows that all the key mechanisms that may lead to large-scale ecosystem damage have been confirmed: release and transport to other areas, bioaccumulation and toxicity. Therefore, munition dumpsites present a risk that is likely to elevate significantly with the progressing corrosion of the shells and containers. As already stated, the problem is currently far from solved and more attention should be paid to it, requiring effective international collaborations in terms of science, politics and governance with a clear common target of reducing the risks of dumped munitions to all the valuable ecosystem services that our seas possess.

The health of the seas is tightly connected to the health of human beings and sustainable development of our societies. The case of short-sighted dumping of war materials exemplifies the dark legacy of our highly negligent and even cynical attitude towards the environment of the past. Our duty towards the future generations would be to stop it, clean up the mess, and make sure it does not happen again. The “out of sight, out of mind” attitude should not form any part of today's marine management.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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