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Benthic communities in chemical munitions dumping site areas within the Baltic deeps with special focus on nematodes

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ABSTRACT

Assessment of biological effects of chemical warfare agents (CWAs) dumped in the Baltic Sea has been one of the tasks of the Chemical Munitions Search & Assessment (CHEMSEA) project. Three sites have been selected for investigation: Bornholm Deep, Gotland Deep and Gdansk Deep. Fauna collected from these locations were compared with the reference area located between the studied regions at similar depths below 70 m. In total, four scientific cruises occurred in different seasons between 2011 and 2013. The total lack of any representatives of macrozoobenthos in all of the investigated dumping sites was noted. As a practical matter, the Baltic deeps were inhabited by nematodes as the only meiofauna representatives. Therefore, nematodes were used as a key group to explore the faunal communities inhabiting chemical dumping sites in the Baltic deeps. In total, 42 nematode genera belonging to 18 families were identified, and the dominant genus was *Sabatieria* (Comesomatidae), which constituted 37.6% of the overall nematode community. There were significant differences in nematode community structure (abundance and taxa composition) between the dumping areas and the reference site (Kruskal–Wallis $H=30.96$, $p<0.0001$). Such clear differences suggest that nematode assemblages could mirror the environmental conditions.

1. Introduction

At the end of World War II, it was necessary to find a fast and economical way to dispose of the enormous quantities of unneeded conventional and chemical munitions. Detonation, emptying and burying were costly, dangerous and very time-consuming solutions. Dumping at sea was found to be the best option for general security and resulted in less problematic outcomes. The largest amount of chemical ammunitions and their containers were dumped into the North Sea and the Baltic Sea immediately after the end of World War II (HELCOM, 1994). The environmental consequences and protection of the sea ecosystem were completely ignored at that time. Based on diverse accidents, especially during fishing activity, a discussion regarding the potential risks for humans and for the environment of previously dumped ammunition arose in the mid-1980s (Theobald, 2001). In this context, the first assessment stated that a long-term threat for the marine environment could not be ruled out and that the considerable lack of knowledge had to be filled by specific investigations.

The corrosion of ammunition and the related eventual leakage of that ammunition into oxygen-containing water and sediment layers resulted in a diffuse release of contained explosives and chemical warfare agents (HELCOM, 1996; Sanderson, 2012). Conventional ammunition, especially trinitrotoluene (TNT), is considered toxic to microorganisms and aquatic plants (Ek, 2005) and toxic to fish at concentrations of 0.7–3.7 mg/l (Haas, 1996). Chemical warfare agents, e.g., Adamsite, Hydrocyanic acid, Clark I and II and mustard are very dangerous aquatic pollutants, especially for living organisms (Lofuto et al., 2010). Hydrocyanic acid, Sarin and Tabun create medium- to long-term persistent contamination zones in the water, with highly toxic concentrations due to their high water solubility and low velocity of hydrolysis (Koch, 2009). Some degraded products of chemical warfare agents (CWA) are even more persistent and are several times more toxic than their original substance (Kaffka, 1996). Therefore, biota may be exposed not only to energetic compounds released to the surrounding environment but also to their numerous transformation products (Munro et al., 1999; Nipper et al., 2009). Despite the potential harmful impacts of CWA, there is no knowledge about their long-term toxicological effects on benthic faunal communities. Some substances have possible carcinogenic, teratogenic or genetic effects (Haas, 1996; Kopecz, 1996). The sudden release of significant quantities of ammunition can have unrecognised consequences for the surrounding environment.

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This study aimed at revealing the structure of faunal assemblages associated with this unique area by providing a first assessment of the meiobenthic communities. Meiofauna is characterised as a separate group of organisms between macrofauna and microfauna in size, which play important roles in organic matter cycles. Because they live in close contact with sediment particles and interstitial water, they are directly exposed to contaminants and, therefore, are suitable for assessing anthropogenic impacts and environmental disturbance. Even more, in many habitats that are severely exposed to pollutants, meiofaunal taxa represent the most important metazoan component, with nematodes being the most diverse and numerically dominant group. Therefore, nematodes were used as a key group to explore the possible impact of chemicals on the surrounding sea bottom environment.

2. Materials and methods

2.1. Study area

The chemical munitions dump sites are located in the areas of Bornholm basin, Gotland Deep and Gdansk Deep. Of the approximately 40,000 t were dumped between 1947 and 1954, approximately 80% contained mustard and the remaining 20% were arsenic-based agents (e.g., Adamsite, Clark I and II and Tabun) (HELCOM, 1994). In most cases, the munitions were thrown overboard either individually (bombs and shells) or in containers, but a number of ships were also sunk (HELCOM, 1996). There were strong indications that some of the munitions were released during transport to the Baltic dumpsites, but the amount dumped was not known (Andrulewicz, 1996; Schultz-Ohlberg, 2001).

The Bornholm site is located in the western Baltic, east of the island of Bornholm. Approximately 32,000 t of chemical weapons (CWs) were dumped in water depths ranging between 70 m and 120 m. The southern part of the Gotland Basin was the area initially designated for the dumping of chemical warfare material under the orders of the Soviet Military Administration (Bruchmann, 1953; Jäckel, 1969). Between May and September 1947, an alleged 2000 t of chemical warfare materials (consisting of approximately 1000 t of CWA) were shipped by the Elbing IV and Elbing VIII from the port of Wolgast to this area, and the CWs were dumped there at depths between 93 m and 120 m (Jäckel, 1969). CHEMSEA findings (Beldowski et al., 2016) indicated that a chemical munitions dumpsite exists in the southern part of the Gdańsk Deep, in an area with a depth ranging between 80 and 110 m. Based on magnetometric and acoustic scans, four wrecks and several dozen munition objects were detected. These included both mustard- and arsenic-containing warfare agent degradation products (Beldowski et al., 2016). However, in the Gdansk Deep, the munitions disposed of 60 years ago are fully buried in soft, muddy sediment.

2.2. Sampling and laboratory analyses

The study was conducted in selected dumping areas of three Baltic Sea basins, Gotland, Bornholm and Gdansk Deeps, and in a reference area located between the dumping sites (Fig. 1). Sediment samples for biological investigation were collected during four cruises from December 2011 to April 2013. Sampling details are presented in Table 1.

Sediment samples were collected using three different sampling tools: Van Veen grab, Box-corer and remotely operated vehicle (ROV). An unequal number of stations were sampled within each study area. In total, sediment samples from 77 stations were collected and analysed for faunal characteristics. At Gotland Deep and Gdansk Deep, 30 and 22 stations were sampled, respectively and from Bornholm Deep and reference area, sediment samples from 10 to 15 stations were obtained, respectively.

Macrofauna samples were collected from the R/V Walther Herwig III (Van Veen grab) in December 2011 and from the R/V Oceania in March, and April/May 2012 (Box-corer). Material was

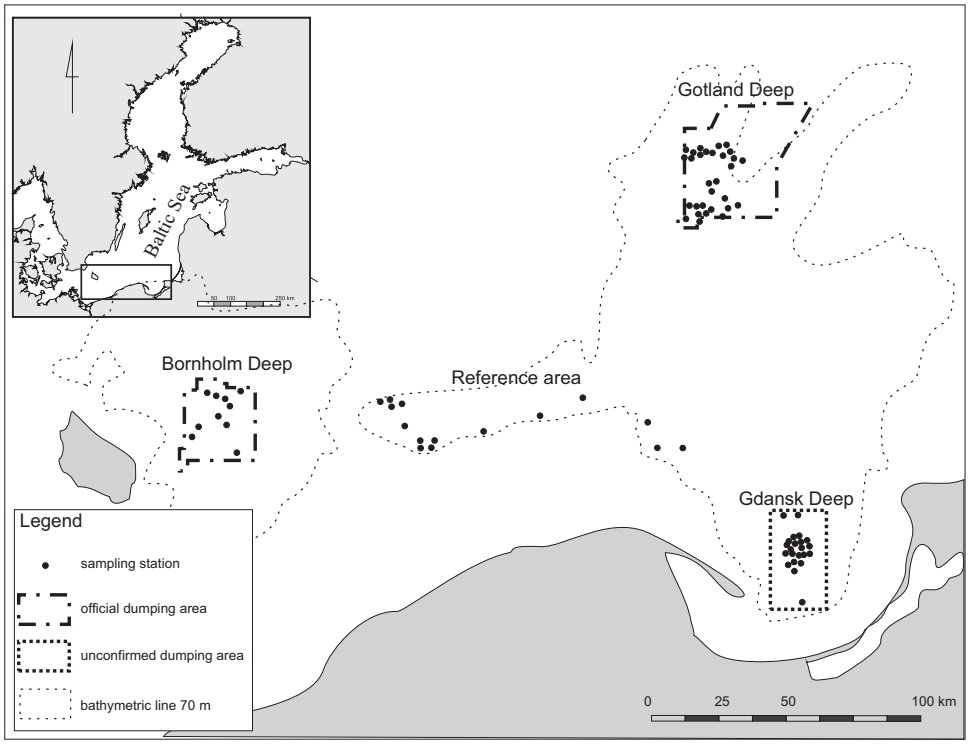

Fig. 1. Map of the study area with location of sampling stations.