A 3.2 Case studies on wrecks filled with chemical munitions

Verification of risk assessment procedures for shipwrecks filled with ammunition

Introduction:

After World War II (WWII), Germany had a large stockpile of chemical weapons (CW) they needed to dispose of. Norwegian authorities gave the Allies permission to dump some of the munitions in an area 14 km X 4 km in size, 25 nautical miles south-east of Arendal in Norwegian waters [1]. Abandoned ships were filled with chemical ammunition, towed out from ports in Germany and scuttled in the deepest part of Skagerrak.

Several investigations of the designated dumping area and adjacent areas have been carried out in order to locate the wrecks (1989, 2002, 2009, 2015 and 2016). In total 36 wrecks, believed to be part of the CW-dumping after World War II, have been located by use of side-scan sonar, mulitibeam echo-sounder and an autonomous underwater vehicle (AUV) with synthetic aperture sonar (SAS) [2, 3, 4, 5, 6]. During these investigations, it was discovered that many wrecks were located outside the designated dumping area. The danger area marked on the nautical charts as "Explosive Dumping Ground" has therefore been extended several times and the current area is shown in Figure 1. An example of Wreck no 13 from the AUV survey conducted in 2015 is shown in Figure 2.

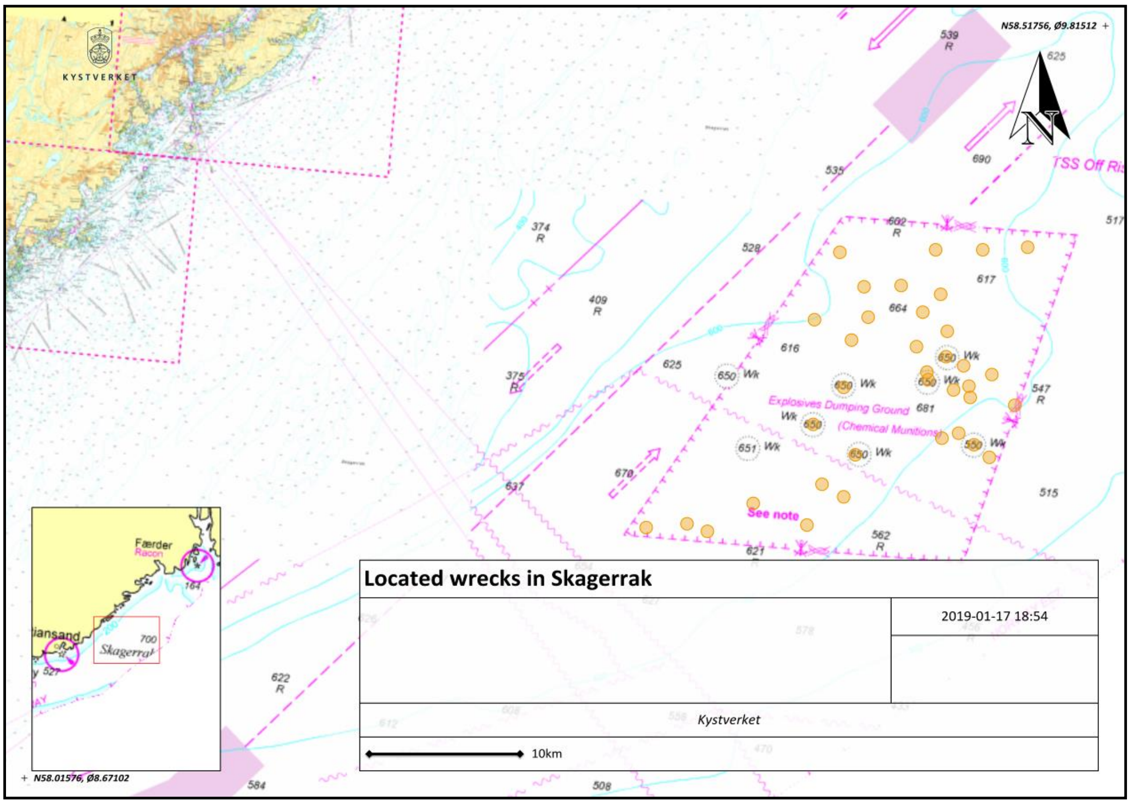

Figure 1 Localised wrecks in the dumping area for chemical ammunition in Skagerrak shown on nautical charts. (Chart: FFI)

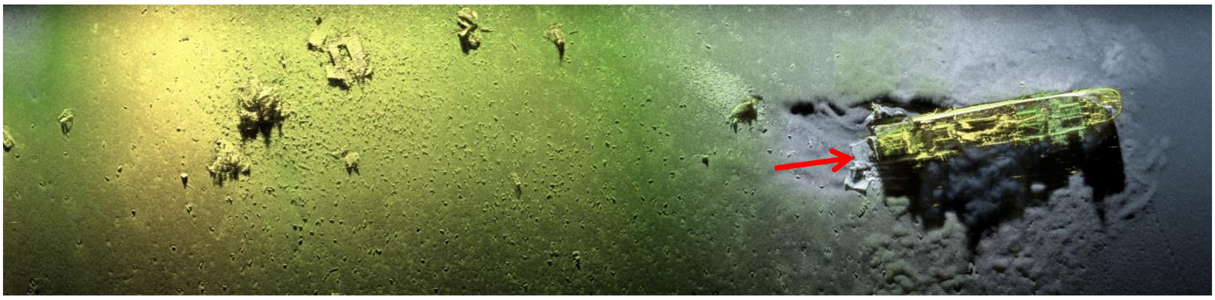

Figure 2 *Wreck no 13 (called wreck no 6 in 2002) from the AUV survey conducted by FFI in 2015. The red arrow shows position of the picture in Figure 3 below. (Photo: FFI)*

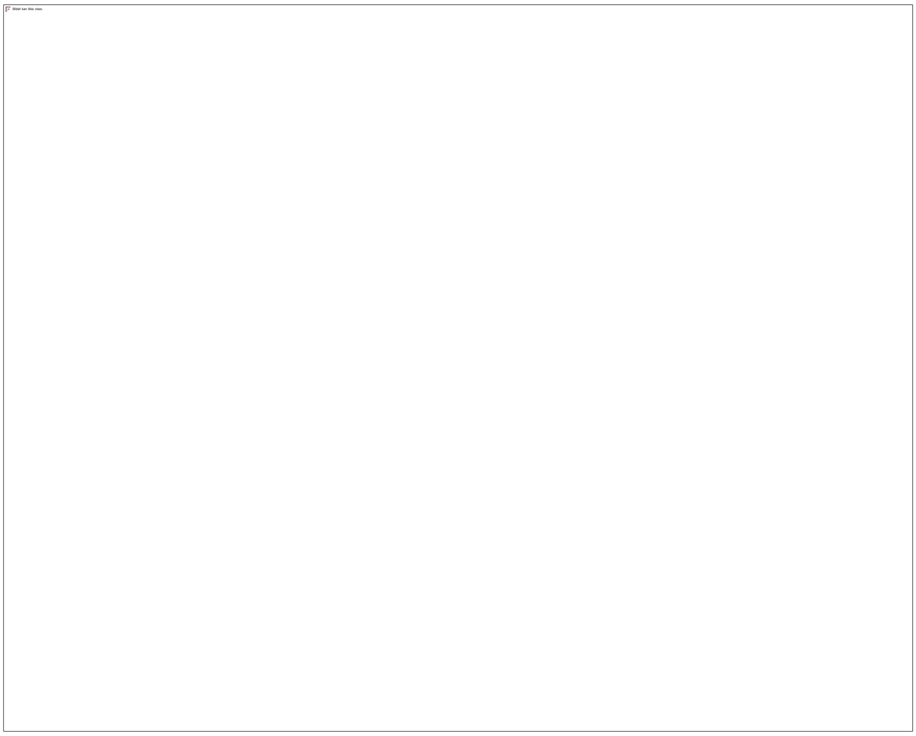

Figure 3 *Snapshot from an underwater video taken at Wreck no 13 in 2002. The picture is taken from the broken hull as shown in Figure 2 above. (Photo: FFI)*

Another deep-water dumpsite was the Måseskär area (27 x 21 km, 259756, 6450499 [SWEREF 99]) (Figure 4a), where only unconfirmed information exists of if and how much CWAs was dumped after WWII. The area is a known good spot for commercial fishing where trawling is performed daily. Furthermore, the area has been investigated during a few expeditions over the years. In a more recent survey in 2015, the area was also thoroughly investigated during a hydrographic survey, using side scan sonar and multibeam echo-sounder, where 28 wrecks were detected. In addition, 13 of the wrecks were further investigated using a Remotely Operated Vehicle (ROV) [7].

In 1992, low concentrations (3.2-1.2 µg/kg) of Yperite (mustard gas) were detected in sediments in the vicinity of the wrecks [8]. In addition, low concentrations (29-4.7 ng/kg) of Clark I were found in Norway lobster (*Nephrops norvegicus*), Witch flounder (*Glyptocephalus* cynoglossus) and shrimp (*Pandalus borealis*) in the area during investigations in 2017-2018 [9]. During the DAIMON project, Chalmers University of Technology with Shirshov institute of Oceanology performed sediment sampling in the area. The results from both studies were then used to investigate and discuss possible management strategies for the dumping area.

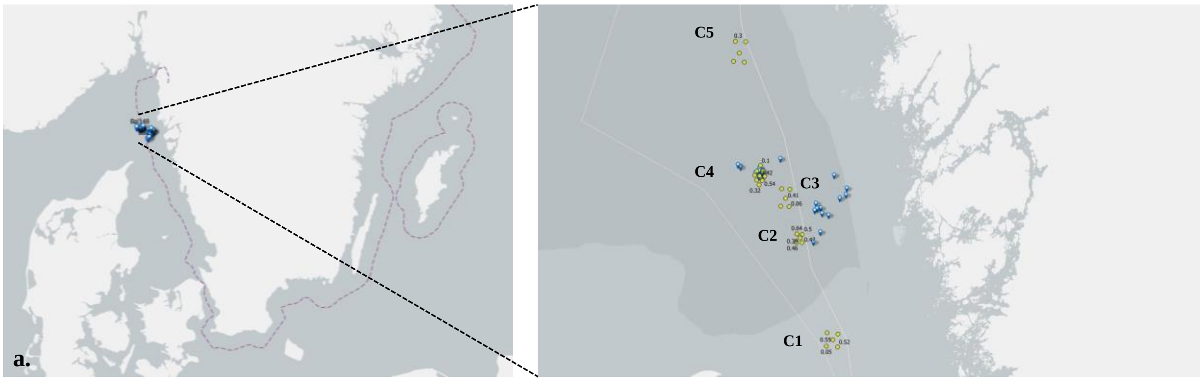

Figure 4 Displayed is the Måseskär CWA dump site (a, left) on the west coast of Sweden, and a magnified image of the dispersal of the 28 wrecks in the area and the sediment sampling points from the Chalmers study (right.) (Illustration taken from [11])

Description of output

This case study will not deal with shipwrecks as such, but the ammunition dumping grounds within and around them (although for simplification it is called “shipwrecks”).

Procedures for survey, identification and risk analysis of conventional munitions developed under DAIMON WP2 will be here verified and tested in practice, and necessary algorithms for result interpretation will be created. Most relevant methods will be selected and a score will be applied for results. This will be done by the early version of decision aid software, and will constitute a step to improve its performance and reliability. Procedures’ description (placed on the website) will include the description of methods used, sequence in which they should be applied and degree of confidence for decision aid estimated for each method. Selection of possible remediation methods will be provided.

Delivered (main) output/investment

Sediment sampling at the Måseskär area

An expedition to the Måseskär dumpsite area was performed in the period June 17-22, 2017 by Akademik Nikolay Strakhov [10, 11]. The dumpsite is located approximately 14 nm west of the island of Måseskär, on the Swedish west coast. The depth in the area is between 190 m and 220 m, compared to the average depth in the adjacent areas, which is about 70 m. The water current from the sea floor and 25 meters up in the water column is mainly north westerly [7]. Five areas were sampled for sediment using a Niemesto corer (Ø 7cm). Two of the areas were in the vicinity (0.5-5 km) of the ship wrecks, one site in between to ship wrecks areas, one area north west of the area with the highest concentrations of wrecks (downstream, 24-29 km to the closest wreck) and the last area was a control area south of Måseskär, 22-26 km from the closest ship wreck). At each area five sites were sampled for pore water and sediments, except for the area with highest concentration of wrecks (cluster 4), were 9 sites where sampled. At each site five sediment cores were taken and sliced at 0-3, 4-6, 7-10 and 11-15 cm (Figure 5). The sliced sediment samples from the five cores were then thoroughly homogenized and pooled, and the pooled samples were divided for analysis of CWA, total arsenic content and meiofaunal community composition. The collected sediment samples were analysed for arsenic by ALS Scandinavia. Sediment and pore-water samples were analysed for remains of chemical weapons by the Finnish Institute for Verification of the Chemical Weapons Convention (VERIFIN) and the meiofauna samples were counted and classified under microscope by the Institute of Oceanology (IOPAN) in Poland. In addition, samples were pre-screened for arsenic on-board using a fast X-Ray Fluorescence (XRF) technique.

Figure 5 *Sampling work on-board Akademik Strakhov in the Måseskär area in June 2017. A Niemesto corer from SIO was used to take virtually undisturbed sediment samples. These were later processed for Arsenic (analysed at CTH), for degradation products of chemical weapons (analysed at VERIFIN) and for meiofauna (analysed at IOPAN, Poland). (Picture from [10])*

In October 2018, two instruments logging parameters such as oxygen, salinity, turbidity and current velocity were deployed at the sea-floor from R/V Akademik Boris Petrov. They will be deployed for a total of 6-12 months at each of the two major dump sites [12].

Muliti-increment sediment sampling

Before the DAIMON project, sediment samples were collected in 2002 and 2015 close to Wreck no 13 in the eastern part of the dump site in the Norwegian part of Skagerrak [3, 13, 14]. Because of the very inhomogeneous concentrations of chemical warfare agents in sediments around the wreck, a new approach tested during DAIMON was to collect sediment samples in squares at different distances from one wreck by using the “multi-increment sampling” technique. The optimal approach was to collect 50 separate cores (10 m apart) in a square with size 70m x 70m. The individual cores from the same square should be sliced in 0-1 cm, 1-3 cm and 3-6 cm depths. All slices from the same depth from all cores taken in the same square should be mixed to one common sample on board (i.e. one common sample for each depth). Such mixed samples would be better suited than spot samples for taking decisions on possible remedial actions in areas with inhomogeneous concentrations of chemical compounds in the sediment [15].

Since the sea depth in the Skagerrak dumping area is between 550 m and 700 m, the time to collect one single sediment sample is considerable. In order to make the sampling more time-efficient, a multi-increment (revolving) sampler was constructed by the Maritime Institute in Gdańsk [16]. This sampler would make it possible to take ten single sediment samples (cores) before it is hoisted to the surface and emptied (Figure 6).

Figure 6 *Multi-increment revolving sampler constructed at Maritime Institute Gdańsk. The sampler allows ten single sediment samples (red arrow) to be collected from the sea floor in one dive. (Photo: FFI)*

The sampler is a semi-autonomous system and is able to move around near the bottom using its own power supply and propulsion system. It also has mounted HD cameras and lightning for documentation of the sampling.

The sampler was tested in June 2017 close to Wreck no 13 in the Norwegian part of Skagerrak. Due to water leakage into the electronics and broken signal cables, only one dive resulting in the collection of eight sediment cores was performed.

Hagfish sampling

Hagfish has been defined as an important organism to be studied because it is abundant close to the sea floor in the areas where munitions have been dumped. Hagfish do also exist at different trophic levels depending on the sea depth and on the existence of other species in their vicinity. Hagfish has an extremely good sense of smell and is also believed to be relatively stationary close to the sea floor, although hagfish movements of 2 km over a 9 month to 4.5 year period have been reported [17].

During the DAIMON cruise in Skagerrak in June 2017 and the FFI test cruise in January 2018, hagfish were collected close to Wreck no. 13 and at locations 1.5 km, 2.2 km and 21 km north-east of the wreck at approximately the same sea depth as the wreck. This makes it possible to investigate the effect of the dumped ammunition on the hagfish at different distances from the wreck.

A rig with truncated soda bottles was used as hagfish trap (Figure 7). After approximately 12 hours, the traps were recovered (Figure 8) and the hagfish were dissected and prepared for transport back to the laboratories.

Figure 7 Rig with hagfish traps (red arrow) and soda bottles with fish used as bait. (Photo: FFI)

Figure 8 Soda bottles with catch of hagfish. (Photo: FFI)

The hagfish samples collected during the cruises in Skagerrak in 2017 and 2018 were analysed with respect to chemical warfare agents and some of their decomposition products both in Norway and in Finland. Histopathological analyses of hagfish samples have been carried out in Norway and Germany.

Description of collected samples

During the DAIMON cruise in Skagerrak in June 2017 and the FFI test cruise in January 2018, hagfish were collected from ten separate sampling rigs drops located close to Wreck no 13 and at positions 1.5 km, 2.2 km and 21 km from the wreck. Several bottles with hagfish were collected from the same drop. Amphipods were also collected at a few sampling stations.

During the DAIMON cruise in July 2018, one multi-incremental sample consisting of eight separate sediment cores was collected. The cores were sliced at 0-1 cm, 1-3 cm and 3-6 cm depths and all slices from the same depth were mixed to one common sample.

The collected samples were analysed using methods developed in A 2.3 and A 2.4 at laboratories in Norway, Finland and Germany.

Risk analysis procedure

Non-numerical guidelines for assessing hazards from chemical warfare agents leaking out from dumped ammunition have been established based on the results from the cruises in Skagerrak. These guidelines will act as starting points in the DAIMON Decision Support Software (DSS), and will be refined when more knowledge concerning the hazards from such dumped ammunition becomes available.

The method gives simple three-colour codes, so called “traffic lights”, to indicate whether the hazard to sediments, water, benthic organisms, pelagic organisms or humans are low (green), intermediate (yellow) or high (red). These traffic lights are based on experimental and estimated leakage rates from dumped ammunition, and available ecotoxicity of selected chemical warfare agents. The agents discussed are tabun, sulphur mustard, and arsenic containing warfare agents. These three groups of compounds have been selected as examples of dumped chemical warfare agents because of their different solubilities, decomposition rates and toxicities. A distinction is also made between effects on water and sediments close to the dumped ammunition (less than 20 m) and in the vicinity of the ammunition (between 20 m and 500 m) as well as benthic organisms living close to the dumped ammunition (less than 50 m) and away from the ammunition (more than 50 m).

A more comprehensive description of the risk analysis procedure is given in a separate document [18].

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