Baltic Sea Environment Proceedings No. 142

Baltic Marine Environment Protection Commission

Chemical Munitions

Dumped in the Baltic Sea

Published by:
HELCOM – Baltic Marine Environment Protection Commission
Katajanokanlaituri 6 B
FI-00160 Helsinki
Finland
www.helcom.fi

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For bibliographic purposes this document should be cited as:
HELCOM, 2013
Chemical Munitions Dumped in the Baltic Sea. Report of the *ad hoc* Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI)
Baltic Sea Environment Proceeding (BSEP) No. 142
Number of pages: 128

ISSN 0357-2994

Language revision: Howard McKee
Editing: Minna Pyhälä and Mikhail Durkin
Design and layout: Leena Närhi, Bitdesign, Vantaa, Finland

Chemical Munitions Dumped in the Baltic Sea

Report of the *ad hoc* Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI)

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1 Executive summary

The continuously increasing scientific knowledge and information resulting from past and on-going activities in the Helsinki Convention Area has made it necessary to update the 1994/95 reports of the ad hoc Working Group on Dumped Chemical Munitions in the Baltic Sea (HELCOM CHEMU).The report at hand was prepared by the ad hoc Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI) and compiled by Poland and Germany. It represents a logical fulfilment of the recommendations given in the HELCOM CHEMU reports. It was necessary to re-adjust the formally drawn conclusions and recommendations in order to adequately reflect the current state of knowledge.

This report presents the available knowledge on dumping and recovery activities from the past. It has been mainly amended by recently found archive material and research findings, and draws conclusions based on these. Even today, there are gaps in knowledge and only a small fraction of potential sources for relevant information has been assessed and made use of, especially historical information in archives.

In accordance with the 1994 CHEMU Report, the total dumping of 40,000 tonnes of chemical warfare materials is re-confirmed. Recent archive investigations indicate that the amounts of warfare agent mixtures contained in those might be slightly higher than estimated earlier (15,000 tonnes compared to 13,000 tonnes reported in BSEP 64B, HELCOM 1996). They have been mainly dumped item-by-item from ships headed for the designated dumping areas. Materials were thrown overboard in the region of target areas as well as en route from the loading harbours (e.g., Wolgast and Flensburg). It is clear that chemical warfare materials were scattered within the dumping areas marked on sea charts, in their vicinity and on the former transport routes. Consequently, there still remains uncertainty about the total amounts, types and exact locations of dumped chemical warfare materials.

Even today, the possibility of people encountering chemical warfare materials while working in the marine environment of the southern and western Baltic Sea cannot be ruled out (e.g., fishermen and workers involved in offshore construction activities). In view of the increasing utilization of the seafloor for economic purposes (e.g., offshore wind farms, sea cables, pipelines), the risk of encountering sea-dumped munitions is increasing.

In addition, in certain areas of concern in the southern Baltic Sea (Germany, Poland and Latvia), beach visitors are at risk of coming into contact with white phosphorus washed ashore. This incendiary agent can cause severe burns and is highly toxic.

Risks associated with unintentional catches of chemical warfare materials are still present for the crews of fishing vessels operating in the vicinity of dumping areas. Relocation of chemical warfare materials has been used as an emergency measure after unintentional catches (e.g. by fishermen), especially in cases where the items were suspected to contain explosives. When encountered during commercial activities, chemical warfare materials have been bypassed rather than relocated.

According to the historical information available, sulfur mustard is the most abundant chemical warfare agent in the dumped munitions. This chemical agent poses a present risk to humans who come into contact with it, and to organisms within its immediate vicinity, taking into account both short- and long-term effects. Compared to the time of the HELCOM CHEMU reports, the amount of active chemical warfare agents has decreased as a result of corrosive disintegration of munitions casings, causing the release and thus the possible degradation of chemical warfare agents. In addition, a small amount of warfare materials has been removed (e.g., caught by fishermen and destroyed by the authorities).

According to existing knowledge, chemicals originating from chemical warfare materials can spread from the disposal sites of the containers due to natural and anthropogenic processes. Sediments within the borders and in the vicinity of the former dumping grounds have been shown to be in various stages of contamination with chemicals presumably originating from chemical warfare materials.

Arsenic-containing warfare agents have been shown to contaminate areas of the sea bottom and to spread both within and outside the dumpsites. In all cases investigated so far, however, no chemical warfare agent parent compounds or degradation products were detected in the water column in measurable quantities. The environmental impact of chemical warfare agent mixtures has not been thoroughly assessed by ecotoxicological means - so far only theoretical considerations and modelling have been used to fill this experimental gap. Little is known about the magnitude of the effect of different chemical warfare agents and the degradation products towards marine organisms. Although no direct observations have been made to date, contemporary scientific studies in other marine regions have indicated that adverse effects are possible for marine biota.

A separate risk is posed by white phosphorus. The nuggets of white phosphorus can be mistaken for amber and ignite upon drying, burning at about 1,300 °C. Each year, several cases of people suffering from severe burn injuries after accidentally coming into contact with white phosphorus are reported.

With regard to gaps in knowledge related to dumped chemical munitions and with a view of on-going national and international activities (e.g., Lithuania, Poland and Germany), this report should be considered as a step in continuing efforts to establish a working process for new updates after significant new information becomes available (e.g., resulting from international research projects such as CHEMSEA). Supplementary technical information related to existing technologies and methodologies for underwater munitions response programs is available at the website of the International Dialogue on Underwater Munitions IDUM (Long 2013).

It should be noted that also regions bordering the 1992 Helsinki Convention area were used for sea-dumping of chemical warfare materials.

Recommendations of HELCOM MUNI (2013)

Contracting Parties are recommended to:

- Carry out, support and facilitate historical research in national and international archives, especially to undertake efforts to get access to still classified documents of relevance e.g., in the archives of the WWII Allies.
- Carry out, support and facilitate technical research, e.g., within international projects, in known and suspected areas using technology specifically suitable for the task.
- Share detailed information about findings both within and outside the Baltic Sea region, taking into account the UN GA Resolution A/RES/65/149. Furthermore, it is advisable to investigate dumpsites bordering the Helsinki Convention area, e.g., the dumpsite off Måseskär.
- Support and facilitate the development of suitable analytical methods and building of analytical capability.
- Support and facilitate the development of suitable guidelines for performing surveys and testing methods.
- Support and facilitate the development of suitable instruments and methods for site-specific risk assessments.
- Transfer procedures and experiences for intentional recovery that exist under the provisions of current international legal instruments.
- Deploy response teams and, on their advice, consider relocation as an acceptable emergency measure.
- Consider this report as a step in an on-going process and to establish a working process for periodical updates after significant new information becomes available.
- Support and facilitate the development and operation of information portals on sea-dumped warfare materials, including white phosphorus in the Baltic Sea region, and other on-going activities at national and HELCOM levels to increase public awareness.
- Support and facilitate national centres or responsible organizations for the collection of information on sea-dumped warfare materials, the coordination of response and training activities for the decontamination of vessels and equipment, as well as the treatment of affected people.
- Carry out, support and facilitate the updating and development of suitable guidelines for all potentially affected groups.
- Update sea charts to reflect the extensions of the formerly designated primary and secondary dumpsites and to ensure that no information is lost on nautical charts when the transition to Electronic Nautical Charts is made.

2 Introduction

This report is an updated version of the 1994 and 1995 HELCOM CHEMU reports on chemical munitions dumped in the Baltic Sea (HELCOM 1994 & 1995). Since the mid-1990s, new technical and scientific developments as well as new information on dumped chemical munitions have become available through projects, organizations, companies and reported incidents.

The Helsinki Commission decided at its 2010 Ministerial Meeting in Moscow to establish an ad hoc HELCOM Expert Group to update and review the existing information on dumped chemical munitions in the Baltic Sea (HELCOM MUNI). HELCOM MUNI meetings were held in Neumünster (Germany), Sopot (Poland), Riga (Latvia), Kaliningrad (Russia) and Copenhagen (Denmark) (Figure 1).

With a view to provide an augmented successor to the original 1994/1995 papers, this report focuses on the dumping activities that took place towards the end of World War II and in the post-war period – it does not include information on chemical munitions dumped after World War I until 1944. While its scope encompasses all chemical warfare materials and white phosphorus stemming from incendiary munitions, the report does not contain information on the dumping of other conventional munitions in the Baltic Sea, nor does it contain any formal environmental risk assessment of sea-dumped chemical munitions for the entire Baltic Sea. Information was provided to the Helsinki Commission (HELCOM) by all HELCOM Contracting States.

This report aims to review information on dumped chemical munitions in the Baltic Sea that has become available after the 1994/1995 CHEMU Report and to check and update the recommendations of the 1994/1995 CHEMU Report.

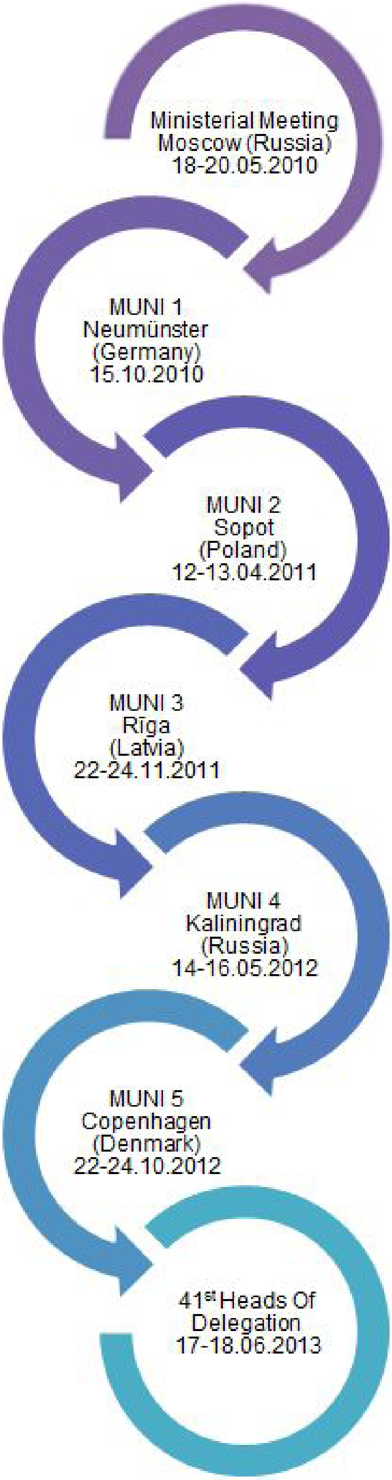


Figure 1: HELCOM MUNI report - milestones and meetings.

2.1 CHEMU report – subjects covered, recommendations & fulfilment

Following intensive media coverage at the beginning of the 1990s on the occurrence of dumped chemical munitions in unknown locations within the Helsinki Convention area, the 14th meeting of the Helsinki Commission in 1993 decided to establish the ad hoc Working Group on Dumped Chemical Munitions (HELCOM CHEMU). Its task was to elaborate a report on the dumping locations and effects of chemical weapons in the marine environment.

Based on national reports concerning dumped chemical munitions in the Baltic Sea area, the HELCOM CHEMU Group, led by Denmark, prepared a Report on Chemical Munitions Dumped in the Baltic Sea (HELCOM 1994). This report was submitted to the 15th Meeting of the Helsinki Commission in 1994 and the main conclusions of the report are summarized below (Figure 2).

Pollution

- Approximately 40,000 tonnes of chemical munitions were dumped into the Baltic Sea after the Second World War. It is estimated that these chemical munitions contained some 13,000 tonnes of chemical warfare agents.
- The locations of the main dumping areas are well known: south-east of Gotland (south-west of Liepaja), east of Bornholm and south of Little Belt.

Hazards

- As the relocation of munitions by hydrodynamical conditions such as currents is unlikely, a threat to coastal areas of the Helsinki Convention Area from residues of warfare agents or chemical munitions washed ashore is unlikely.
- Chemical warfare agents break down at varying rates into less toxic, water-soluble substances. Some compounds, however, show an extremely low solubility and slow degradation (e.g., viscous mustard gas, Clark I and II, and Adamsite). As these compounds cannot occur in higher concentrations in water, wide-scale threats to the marine environment from these dissolved chemical warfare agents can be ruled out.

Risk management

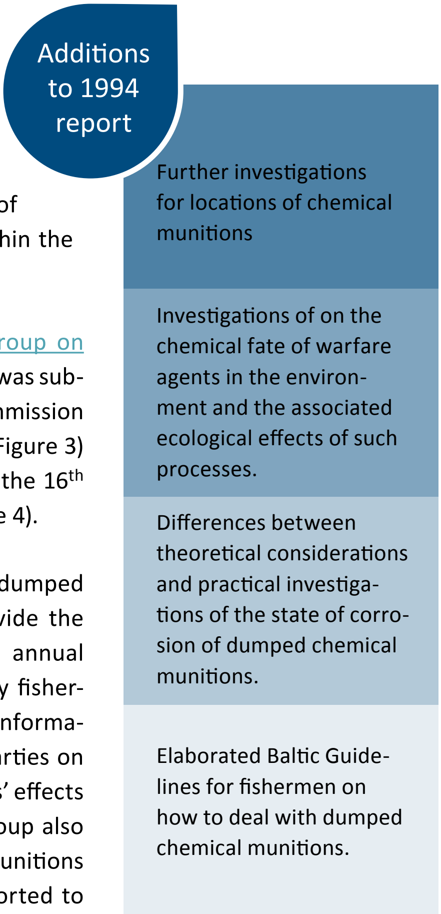
- Since chemical munitions are still a risk for the crews of fishing vessels operating in parts of the Baltic Sea adjacent to the main dumping areas, special guidelines have been prepared for distribution by HELCOM at the national level.
- As risks connected with the possible recovery of chemical munitions are high, this management option should not be recommended.
- A regular (annual) reporting on incidents involving dumped chemical munitions should be continued in order to obtain more comprehensive information about the locations, amounts as well as the state and threats related to dumped chemical munitions.

Figure 2: Main conclusions of the 1994 HELCOM CHEMU report (HELCOM 1994).

The 15th meeting of the Helsinki Convention welcomed the report by HELCOM CHEMU and mandated the ad hoc working group to continue for one more year with the task to follow and coordinate the implementation of the recommendations given in its report within the area of the Helsinki Convention.

The Final Report of the ad hoc Working Group on Dumped Chemical Munitions (HELCOM 1995) was submitted to the 16th Meeting of the Helsinki Commission in 1995. It contained additional information (Figure 3) and was finally amended by the decisions of the 16th meeting of the Helsinki Commission (*cf.* Figure 4).

Denmark offered to act as Lead Country on dumped chemical munitions and was willing to provide the Baltic Sea states and the Commission with annual reports on catches of chemical munitions by fishermen. Moreover, Denmark would also share information provided by the HELCOM Contracting Parties on scientific and practical studies of the munitions' effects on the marine environment. The working group also agreed that the state of corrosion of caught munitions should be investigated and the findings reported to Denmark.



Further investigations for locations of chemical munitions

Investigations of on the chemical fate of warfare agents in the environment and the associated ecological effects of such processes.

Differences between theoretical considerations and practical investigations of the state of corrosion of dumped chemical munitions.

Elaborated Baltic Guidelines for fishermen on how to deal with dumped chemical munitions.

Figure 3: Additional information included in the final report of the ad hoc Working Group on Dumped Chemical Munitions (HELCOM 1995).

2.2 MUNI report – scope & perspectives

Since 1995, various investigations, in archives and also in dumping areas in situ - have added to the knowledge on the types, amounts and properties of chemical warfare materials dumped in the Baltic Sea. Moreover, scientific studies on the effects of chemical warfare materials on the environment and on humans have been carried out, which have resulted in tools and data for testing while also providing methodological support for risk assessments.

In 2010, the 65th session of the UN General Assembly adopted Resolution A/RES/65/149 on 'Cooperative measures to assess and increase awareness of environmental effects related to waste originating from chemical munitions dumped at sea' (*cf.* Chapter 2.3.1.2.2). This report is a regional fulfilment of this UNGA resolution.

The scope of the HELCOM MUNI report is derived from the 1994/1995 HELCOM CHEMU reports, with special focus on their recommendations and principal conclusions (*cf.* Figure 4).

Risk management

- CPs were requested to provide Denmark with information on all national and international activities concerning dumped chemical munitions by the end of June every year.
- Combatting Committee was requested to develop the Guidelines for appropriate authorities on how to deal with incidents where chemical munitions are caught by fishermen and to include them into the HELCOM Combatting Manual.
- CPs were recommended to provide the appropriate associations and organizations of fishermen in their respective countries with relevant national guidelines developed on the basis of the HELCOM Guidelines attached to this Report.
- CPs were recommended to conclude agreements concerning financial aspects of decontamination of fishing vessels not flying the flag of the country undertaking the decontamination.

Scientific investigations

- CPs were recommended to carry out further investigations for location and characterization of dumped chemical munitions.
- CPs were invited to assist the countries in transition in such investigations.
- CPs and members of the European Union, were encouraged to make arrangements with the European Commission for the coverage of the entire Convention Area by projects which may have relevance to dumped chemical munitions.
- CPs were encouraged to proceed with investigations of chemical processes and ecological effects of warfare agents to the marine environment and with field studies at the dumping sites.
- Environment Committee was requested to coordinate future investigations of the chemical processes of warfare agents and their ecological effects.

Figure 4: Selected requests, recommendations, encouragements and invitations to Contracting Parties (CPs) and subsidiary groups of the Helsinki Commission resulting from the 16th Meeting of the Helsinki Commission and contained in the 1995 final HELCOM CHEMU report (HELCOM 1995).

The scope of HELCOM MUNI's work, as defined by the Helsinki Commission, includes the tasks depicted in Figure 5. Of these, the Contracting Parties were asked, in particular, to carefully review today's validity of the general statements made more than 15 years ago.

Review

- Check whether the general conclusions of the HELCOM CHEMU 1994/1995 reports are still valid.
- Check whether all recommendations as set out in the HELCOM CHEMU 1994/1995 reports are fulfilled in a satisfactory way.
- Identify obstacles that may have led to unsatisfactory fulfillment.
- Review the existing reporting system together with lead country Denmark with the aim of involving HELCOM Contracting Parties more actively into the reporting obligation.

Update

- Compile additional information on dumping activities, especially after World War II.
- Use suitable models in order to assess the ecological risks related to sea-dumped chemical munitions.
- Develop additional recommendations (including the need for further research) as deemed necessary.
- Update, or as deemed necessary, develop Guidelines for affected groups. e.g. fishermen, based on existing national guidelines.

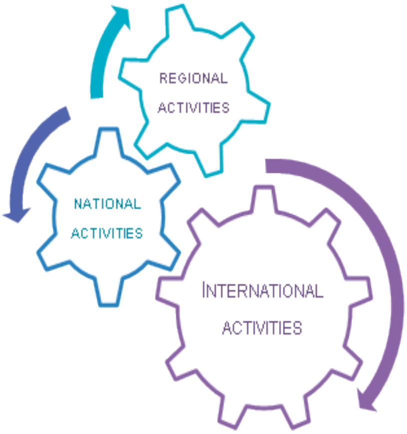
Figure 5: The scope of HELCOM MUNI tasks as defined by the Helsinki Commission.

Taking into account the new information available since 1995, all Contracting Parties felt that while the new details should be included in the updated report, in general, the principal conclusions and recommendations of the CHEMU report are still valid. The fulfilment of the recommendations given in the CHEMU 1994/1995 reports was considered as only partly satisfactory, especially due to the low reporting frequency of incidents and the lack of financial compensation systems for fishermen in all Contracting Parties except Denmark.

The Contracting Parties considered the further elaboration of the CHEMU 1994/1995 reports as beneficial and expressed their receptiveness to changes, if deemed necessary. More precisely, the guidelines, policies and procedures for dealing with encounters of munitions were seen as requiring an update in order to clarify possible re-disposal or recovery options on a case-by-case basis. The national practices in Denmark and Sweden were considered as a suitable starting point for this task.

2.3 National and international activities since 1995

2.3.1 Managerial initiatives



2.3.1.1 National activities

2.3.1.1.1 Russia

In 1995, Russia arranged a NATO Advanced Research Workshop on sea-dumped chemical munitions in Korolyov. Furthermore, Russia initiated and supported several full-scale research programs (*cf.* Chapter 2.3.2.1.4)

2.3.1.1.2 Lithuania

At Lithuania's initiative, the United Nations unanimously adopted the resolution on sea-dumped chemical munitions in December 2010 (*cf.* Chapter 2.3.1.2.2). This was the first resolution that Lithuania has independently submitted to the United Nations for adoption. During the negotiations on the adoption of the resolution at the United Nations, Lithuania gained full support from all member states of the European Union. Along with Lithuania, the resolution was co-authored by 15 countries. The adoption of the resolution is a result of a long and consistent Lithuanian diplomatic activity. Lithuania began organizing international seminars on sea-dumped chemical weapons in 2008, continuing in 2011 in Vilnius and in 2012 in Gdynia (co-organized by Poland) (*cf.* Figure 9), and keeps the public informed via the information portal www.seadumpedcw.org.

In addition, the International Scientific Advisory Board on Dumped Chemical Weapons was established at Lithuania's initiative in The Hague and started its activities in 2010 (*cf.* Chapter 2.3.1.2.6 on IDUM). The Scientific Board gathers world-renowned representatives from environmental organizations as well as scientists, researchers and experts working in the fields of environment protection and the destruction of chemical weapons from Australia, Belgium, Canada, France, Germany, Japan, Lithuania, Poland, Russia, Sweden and the U.S.A and provides qualified scientific and technological information, evaluations and analytical recommendations regarding sea-dumped chemical weapons.

2.3.1.1.3 Poland

In the years 1997 and 1998, two international scientific symposia dedicated to chemical weapons dumped in the Baltic Sea were held at the Westerplatte Heroes Polish Naval Academy (PNA) in Gdynia (*cf.* Chapter 2.3.1.2.7). The substantial interest in these conferences reflected the shared concerns prevailing in the public and military, and at the governmental level. As a consequence, the Commander of the PNA established the Chemical-Ecological Information Centre (Centrum Informacji Chemiczno-Ekologicznej, CICE) in 1999 in order to carry out an assessment of the threat emanating from chemical munitions dumped in the Baltic Sea and their impact on the marine environment.

In later years, the problem of dumped chemical munitions has gained a new dimension due to an increase in planned exploitation of the seafloor for large construction and infrastructure projects. A need was thus identified for the assessment of all consequences resulting from the possible disturbance of sea-dumped munitions during such undertakings. Consequently, the topic has often been on the agenda of scientific conferences related to the safety of sea basins (*cf.* Chapter 2.3.1.2.7). Of special note is the international conference 'Environmental Threats to the Baltic Sea', held in 2007 under the patronage of the Marshal of the Senate, Bogdan Borusewicz, and Chairman of the Agriculture and Environmental Protection Committee, Jerzy Chróścikowski, in Warsaw, and the 'International Seminar on Sea-dumped Chemical Weapons' in Vilnius in 2008. The latter meeting was supported by a Polish paper entitled 'The North European Pipeline and Chemical Warfare Agents Dumped in Bornholm Basin', which was subsequently discussed with representatives of the Ministry of Economy and the Ministry of Foreign Affairs of Sweden during a seminar in Stockholm.

As mandated by the Minister of Environment (5 January 2010), the Chief Inspector of Environmental Protection, Andrzej Jagusiewicz, serves as the leader of the flagship project 3.2. 'Assess the need to clean up chemical weapons' under Priority Area 3 'To reduce the use and impact of hazardous substances' of the EU Strategy for the Baltic Sea Region (*cf.* Chapter 2.3.2.2.2 on CHEMSEA project). He is also a member of the International Scientific Advisory Board (ISAB) on Sea-Dumped Chemical Weapons to the Government of Lithuania and is actively engaged in the work of the International Dialogue on Underwater Munitions (*cf.* Chapter 2.3.1.2.6 IDUM). The Third Dialogue took place in Sopot, Poland, in 2011 and was co-organized by the Chief Inspectorate of Environmental Protection. The Fourth Dialogue was co-chaired by the Chief Inspector of Environmental Protection and took place in San Juan, Puerto Rico, in October 2012.

In support of the Lithuanian initiative, Poland organized a workshop on the environmental effects related to waste originating from chemical munitions dumped at sea. The event was co-organized by the Chief Inspectorate of Environmental Protection and the Polish Naval Academy and took place on 5 November 2012 in Gdynia at the premises of Polish Naval Academy. One of the main purposes of the workshop was to consider the elaboration of a reporting model for the strategy towards implementation of the UN General Assembly resolution A/RES/65/149 (*cf.* Chapter 2.3.1.2.2).

The newest national project ‘Poland for the Baltic Sea’ is coordinated by the Chief Inspectorate of Environmental Protection and financed by the National Fund for Environmental Protection and Water Management. One of the project’s aims is to communicate the subject of chemical munitions and its impact on various groups of stakeholders to Polish civil society. On 19 November 2012, a conference was held in the framework of this project in Szczecin. The audience consisted mostly of fishermen, and representatives of tourism and local governments.

2.3.1.1.3 Sweden

In 2009, the Swedish government gave several Swedish authorities the task of presenting a new information strategy regarding mines, unexploded ordnance and chemical munitions. The strategy aimed to assess the risk groups, determine the information products to be used for the different risk groups, identify adequate information channels, and specify the information to be presented in adequate pictures and charts.

The rationale for expanding the group that might be exposed to chemical munitions is based on two Swedish incidents that demonstrated the existence of an imminent risk. It was accidentally discovered that chemical warfare materials could be transported from known areas of concern into densely populated areas. On 4 April 2001, a trawler outside the coast of Blekinge found a sulfur mustard bomb in the net and transported it to the harbour at Nogersund where it was placed on one of the jetties. In the second incident, which took place in December 2005, a fisherman caught a mine in the trawl and transported it into the harbour of Gothenburg with the result that part of the port and city had to be closed down.

The Swedish working group identified the following possible risk groups: recreational divers, professional divers and sub-surface entrepreneurs; professional fishermen; Swedish harbour workers; and rescue and alarm services professionals (HELCOM 2011b). The group has produced a sticker, a pamphlet, an advertisement and an educational package (Figure 6).

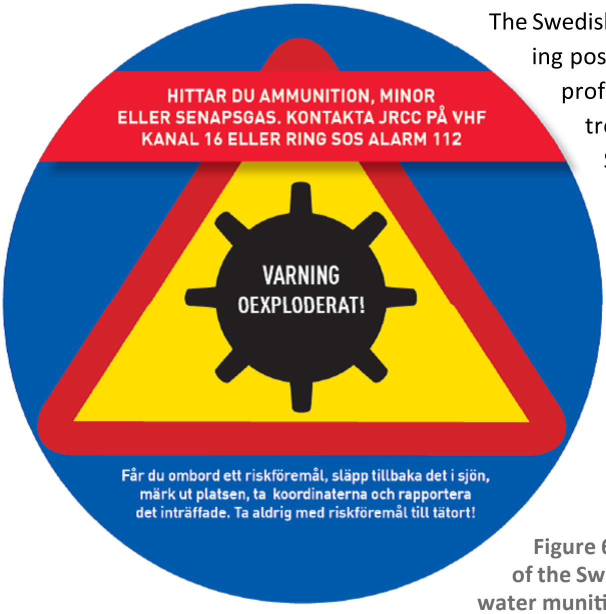


Figure 6: A munitions awareness sticker - part of the Swedish information campaign on underwater munitions (HELCOM 2011b).

2.3.1.1.4 Germany

In the resumption and broadening of Germany's cross-administrative activities related to sea-dumped chemical munitions in the early 1990s (BSH 1993), an expert working group on conventional and chemical warfare materials in German marine waters was established within Germany's official organization framework of marine environment protection. Initiated in 2008 following an initiative of Schleswig-Holstein, formalized in 2009 and consisting of representatives from the coastal states and the federal government, the ad hoc working group finalized its work by publishing its 1,100-page outcome report 'Munitions in German Marine Waters – Stocktaking and Recommendations (Effective 2011)' in December 2011 (Böttcher et al. 2011). In response to the substantial public interest and the transparency expected from nature conservation interest groups, the online publication of the outcome report on the dedicated platform www.underwater-munitions.de (or www.munition-im-meer.de) was accompanied by a symposium attended by the media, administration and industry representatives together with scientists and various interest groups.

With the positive reception and ensuing constructive criticism, i.a. by non-governmental organizations, regarding the systematic course embarked upon and with respect to the recommendations made in terms of work still to be done, the former working group was re-established in 2012, strengthened by representatives of additional key institutions and equipped with an open-ended mandate.

The main task of the successor group for Germany's Program on Underwater Munitions is to oversee the fulfilment of the recommendations given in the 2011 report concerning historical research and technical exploration, investigation and monitoring of environmental effects, handling of dangerous situations, and establishment and maintenance of a reporting and documentation system. Charged by the conference of Ministers of the Interior of the German coastal states, a central reporting office for munitions encounters was established in the national centre for maritime security under the auspices of Schleswig-Holstein and started its operative work on 1 January 2013.

Since the situation concerning munitions will change continuously, the outcome report of the expert group was designed to be a living and growing document (which was updated e.g. in January 2013). Accordingly, regular updates and enhancements are envisaged and will be transparently presented on the public-orientated website (www.underwatermunitions.de or www.munition-im-meer.de). In Germany, this systematic approach is seen as the only way of getting closer to a solution of this problem which concerns society as a whole.

2.3.1.2 International activities

2.3.1.2.1 Chemical Weapons Convention

The Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention or CWC), which entered into force on 29 April 1997 (after the publication of the 1995 HELCOM CHEMU Report), does not require declaration of chemical weapons dumped in the sea prior to 1 January 1985 (Article III, paragraph 2).

The CWC aims to eliminate an entire category of weapons of mass destruction by prohibiting the development, production, acquisition, stockpiling, retention, transfer or use of chemical weapons by States Parties. All HELCOM Contracting Parties are also parties to the Organization for the Prohibition of Chemical Weapons (OPCW), the implementing body of the CWC.

2.3.1.2.2 UNGA resolution on sea-dumped chemical munitions

International efforts sponsored by the Government of Lithuania resulted in the unanimous passing of the United Nations General Assembly (UNGA) Resolution A/RES/65/149 entitled 'Cooperative measures to assess and increase awareness of environmental effects related to waste originating from chemical munitions dumped at sea' at the 65th session of the UN General Assembly (UNGA 2011). The main decisions are summarized in Figure 7.

UN General Assembly Resolution A/RES/65/149

- *notes* the importance of raising awareness of the environmental effects related to waste originating from chemical munitions dumped at sea;
- *invites* Member States and international and regional organizations to keep under observation the issue of the environmental effects related to waste originating from chemical munitions dumped at sea and to cooperate and voluntarily share relevant information on this issue; and
- *invites* the Secretary-General to seek the views of Member States and relevant regional and international organizations on issues relating to the environmental effects related to waste originating from chemical munitions dumped at sea, as well as on possible modalities for international cooperation to assess and increase awareness of this issue, and to communicate such views to the General Assembly at its sixty-eighth session (in 2013) for further consideration.

Figure 7: Decisions of the UN General Assembly (UNGA 2011).

2.3.1.2.3 NATO

The issue of sea-dumped chemical weapons has also intermittently been on the agenda of the North Atlantic Treaty Organization (NATO). A NATO-sponsored advanced research workshop on sea-dumped chemical munitions was held in Russia in 1995; a second conference was held in Italy in 1996; and most recently, the topic was also discussed at a NATO Science for Peace and Security Program (SPS) advanced research workshop in Riga in 2012. A project proposal on monitoring of dumped munitions in the Baltic Sea (MODUM) has been submitted for consideration by NATO SPS (*cf.* Chapter 2.3.2.2.3).

The 1996 NATO report NATO and Partner Countries Study Defense-Related Radioactive and Chemical Contamination also deals with the issue of sea-dumped munitions, and states, among other things, that the most outstanding example of cross-border contamination is the dumping of large quantities of chemical weapons into the Baltic Sea, the Skagerrak and possibly the Arctic Sea (Martens et al. 1996).

2.3.1.2.4 HELCOM

Since the finalization of the HELCOM CHEMU report in 1995 (see Chapter 2.1), Denmark, as HELCOM Lead Party in the field of dumped chemical munitions, has annually been compiling information submitted by the HELCOM countries on the number of incidents where fishermen have netted sea-dumped chemical munitions (*cf.* Chapter 4.3.1). These reports were annually submitted for consideration to the HELCOM Group on Response and Preparedness to incidents involving oil and harmful substances (HELCOM RESPONSE) and the Monitoring and Assessment Group (HELCOM MONAS). Also new scientific information, e.g., the outcomes of the MERCW Project (*cf.* Chapter 2.3.2.2.1) has been submitted to HELCOM MONAS for consideration.

2.3.1.2.5 OSPAR

There have also been activities related to dumped chemical munitions within the framework of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). Information on the locations of sea-dumped chemical and conventional munitions and warfare materials within the OSPAR Convention Area has been compiled in a report by the OSPAR Commission (2005): Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area (OSPAR 2005).

In 2003, OSPAR adopted OSPAR Recommendation 2003/2 on an OSPAR Framework for Reporting Encounters with Marine Dumped Conventional and Chemical Munitions. This Recommendation entered into force on 2 July 2004. The reporting deadlines under Recommendation 2003/2 were set for 1 September 2005

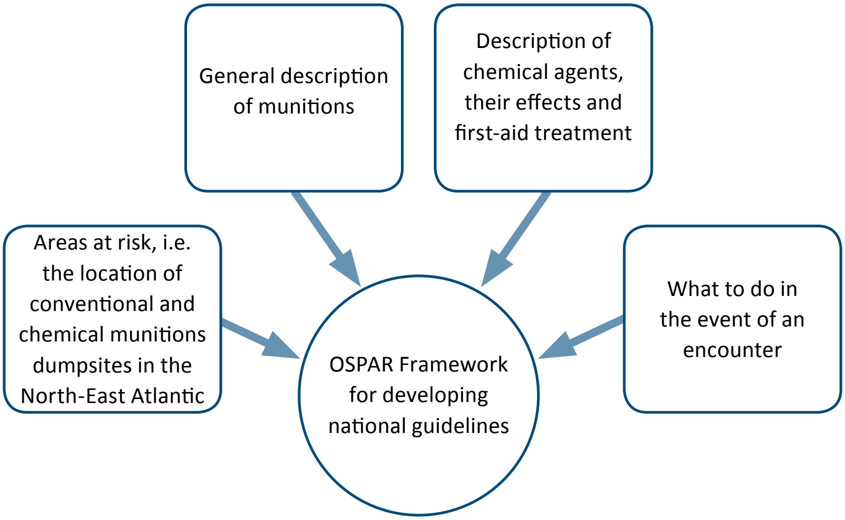


Figure 8: Background information provided by the OSPAR framework for developing national guidelines (OSPAR 2004).

and every three years thereafter (OSPAR 2009a). The Contracting Parties were encouraged to report clusters of encounters for the purpose of identifying where management measures may be required as soon as such clusters became evident. In order to improve the analysis of encounters and the associated identification of clusters, this Recommendation has since been updated by OSPAR Recommendation 2010/20 (OSPAR 2010). The 2010 Recommendation calls for yearly reporting and states that the OSPAR Commission will create, maintain, and make available to the public a database of encounters with conventional and chemical munitions, including chemical warfare agents and white phosphorus in any type of receptacle, weapon or munitions.

The latest assessment of the impact of dumped conventional and chemical munitions in the OSPAR area, based on data available until 2009, was published in the OSPAR 2010 Quality Status Report (OSPAR 2009b).

While acknowledging that some Contracting Parties already have national guidance, OSPAR published ‘A framework for developing national guidelines for fishermen on how to deal with encounters with conventional and chemical munitions’ in 2004 (*cf.* Figure 8) (OSPAR 2004).

2.3.1.2.6 International Dialogue on Underwater Munitions

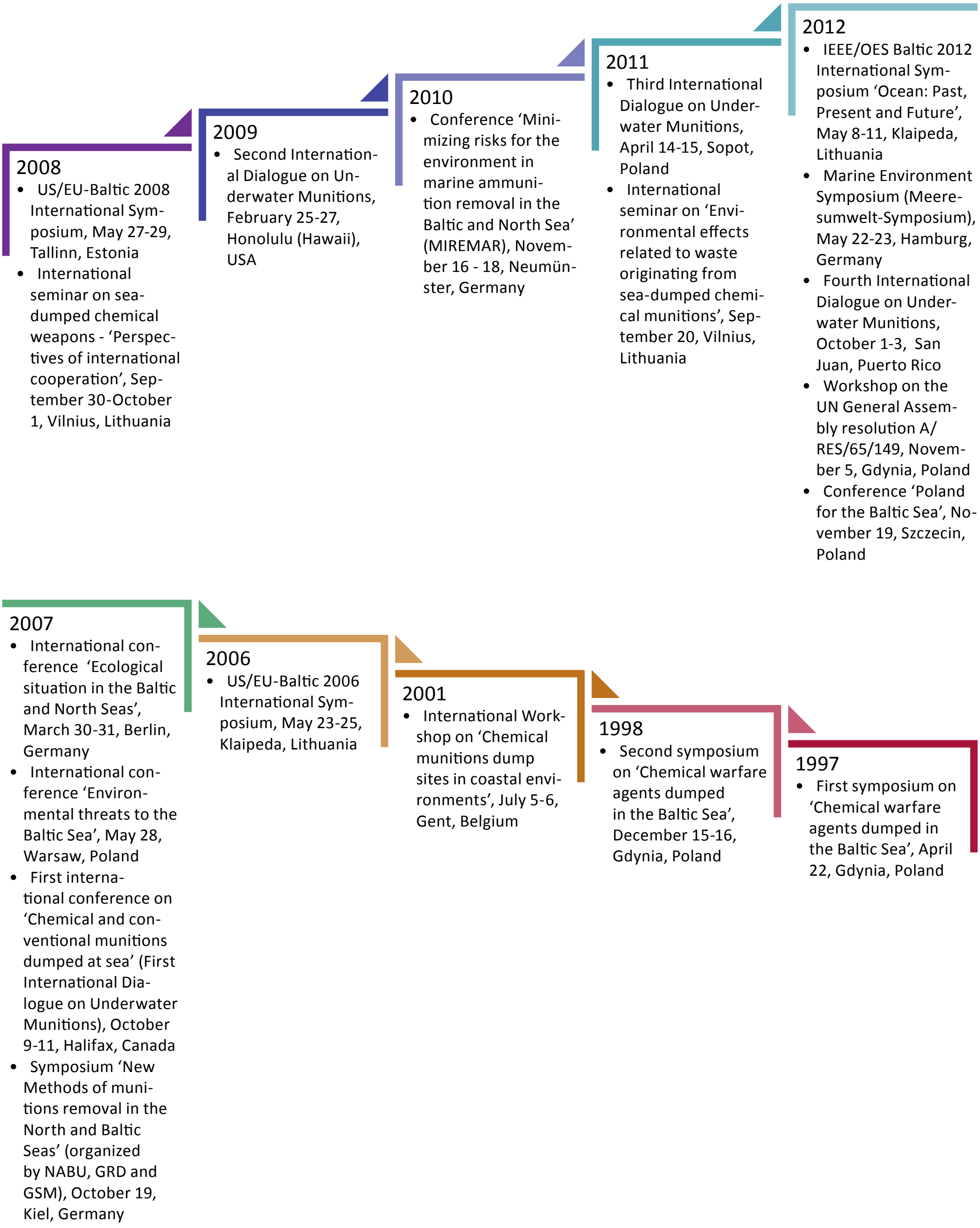
The International Dialogue on Underwater Munitions (IDUM) was established as a series of international conferences rooted in Northern America and is strongly affiliated to its marine research and explosive ordnance disposal industry. IDUM’s mission is to promote the creation of an internationally binding treaty on all classes of underwater munitions that would encourage countries to collaborate on underwater munitions policy, research, science, responses and a donor trust fund.

IDUM collaborates with international leaders and organizations to better understand the socio-economic impact of decaying munitions on both human health and the environment. This is facilitated through international diplomacy, via national and international programs, dialogues, conferences, workshops, committees, senate hearings and international commissions. The International Scientific Advisory Board (ISAB) on Sea-Dumped Chemical Weapons in The Hague (*cf.* Chapter 2.3.1.1.2) provides advice to IDUM. Furthermore, together with the Marine Technology Society Journal (MTSJ), IDUM has published three special international issues on the Legacy of Underwater Munitions: Science, Technology and Potential Responses (Symons & Carton 2009, Carton & Long 2011, Carton & Long 2012). With regard to public awareness, IDUM is working on two international documentaries on sea-dumped munitions and towards the establishment of regional representatives.

2.3.1.2.7 Conferences

Since the finalization of the 1994/1995 CHEMU report, several interest groups, governmental and non-governmental organizations have addressed the topic of sea-dumped munitions and warfare materials and discussed the associated threats in conferences and workshops (*cf.* Figure 9). While also reflecting the increasing interest in the topic, these conferences have raised awareness of the problem and provided valuable insights and contributions.

Most notably, conferences within the framework of the International Dialogue on Underwater Munitions (IDUM) were held in Halifax (Canada) in 2007; in Honolulu (Hawaii, USA) in 2009; in Sopot (Poland) in 2011; and in San Juan (Puerto Rico) in 2012 (*cf.* Figure 9).



2008
- US/EU-Baltic 2008 International Symposium, May 27-29, Tallinn, Estonia
- International seminar on sea-dumped chemical weapons - ‘Perspectives of international cooperation’, September 30-October 1, Vilnius, Lithuania

2009
- Second International Dialogue on Underwater Munitions, February 25-27, Honolulu (Hawaii), USA

2010
- Conference ‘Minimizing risks for the environment in marine ammunition removal in the Baltic and North Sea’ (MIREMAR), November 16 - 18, Neumünster, Germany

2011
- Third International Dialogue on Underwater Munitions, April 14-15, Sopot, Poland
- International seminar on ‘Environmental effects related to waste originating from sea-dumped chemical munitions’, September 20, Vilnius, Lithuania

2012
- IEEE/OES Baltic 2012 International Symposium ‘Ocean: Past, Present and Future’, May 8-11, Klaipeda, Lithuania
- Marine Environment Symposium (Meeresumwelt-Symposium), May 22-23, Hamburg, Germany
- Fourth International Dialogue on Underwater Munitions, October 1-3, San Juan, Puerto Rico
- Workshop on the UN General Assembly resolution A/RES/65/149, November 5, Gdynia, Poland
- Conference ‘Poland for the Baltic Sea’, November 19, Szczecin, Poland

2007
- International conference ‘Ecological situation in the Baltic and North Seas’, March 30-31, Berlin, Germany
- International conference ‘Environmental threats to the Baltic Sea’, May 28, Warsaw, Poland
- First international conference on ‘Chemical and conventional munitions dumped at sea’ (First International Dialogue on Underwater Munitions), October 9-11, Halifax, Canada
- Symposium ‘New Methods of munitions removal in the North and Baltic Seas’ (organized by NABU, GRD and GSM), October 19, Kiel, Germany

2006
- US/EU-Baltic 2006 International Symposium, May 23-25, Klaipeda, Lithuania

2001
- International Workshop on ‘Chemical munitions dump sites in coastal environments’, July 5-6, Gent, Belgium

1998
- Second symposium on ‘Chemical warfare agents dumped in the Baltic Sea’, December 15-16, Gdynia, Poland

1997
- First symposium on ‘Chemical warfare agents dumped in the Baltic Sea’, April 22, Gdynia, Poland

Figure 9: Conferences and workshops on sea-dumped chemical warfare materials since 1995.

2.3.2 Investigations in the Baltic Sea

2.3.2.1 National activities

2.3.2.1.1 Denmark

The Danish National Database for Marine Data project has been collecting water chemistry data in the Bornholm Basin along the eastern edge of the dumping ground marked on sea charts several times per year since 1972. Samples are taken through the entire water column at 20 m intervals (DMU 2011).

Furthermore, for over ten years the Danish Navy has routinely documented the cases of accidentally fished munitions, also assessing the state of corrosion of munitions objects.

2.3.2.1.2 Germany

A magnetometric and acoustic survey has been conducted on the transport routes in the Pomeranian Bay by the Federal Maritime and Hydrographic Agency of Germany assisted by the Baltic Sea Research Institute (Schulz-Ohlberg et al. 2002). During eight cruises in German waters during 1994-1997, a corridor of 5 km breadth and 40 km length of the total approximately 220 km long former transport route to the designated Bornholm (and Gotland) dumping areas was investigated. The grid of sonar and magnetometer measurements was potentially dense enough to find large objects or piles of small objects. Detected surface objects were inspected by video.

2.3.2.1.3 Poland

In 1998-1999, the Military University of Technology in Warsaw analyzed a solidified lump of sulfur mustard which had been accidentally fished from the Gotland dumpsite in January 1997 (Mazurek et al. 2001). Apart from military scientific institutions, very important contributions to the assessment of the scale of threat from the chemical munitions dumped in the Baltic Sea have come from the Institute of Sea Fisheries in Gdynia, the University of Gdańsk, the Maritime Institute in Gdańsk and the Institute of Oceanology of the Polish Academy of Science.

2.3.2.1.4 Russia

National research activities on dumped chemical munitions were carried out from 1994 to 2007, both within national and international programs, and included altogether nine dedicated scientific cruises. Apart from the 'World Ocean' research program which ran until 2007, other programs funded by the Ministry of Natural Resources (Marine Environmental Patrol - MEP) and funded by the Russian Ministry of Emergency Response were conducted until 2006. Besides the above mentioned institutes, other research organizations also took part in those activities.

The A. P. Karpinsky All-Russian Institute of Geological Research (VSEGEI), in St. Petersburg, and the P. P. Shirshov Institute of Oceanology - Atlantic Branch (SIO AB) in Kaliningrad, started collaborating in 1997, and have since 2000 performed a joint project supported by the Russian Federal Program 'World Oceans', aiming at oceanographic and geo-environmental monitoring of chemical warfare material dumpsites (Paka & Spiridonov 2002).

Six cruises were carried out with RV "Professor Shtokman" during 1997-2001, and while the project concentrated mainly on the Bornholm and Gotland Basins, the Gdańsk Deep and the Słupsk Furrow, there were also three cruises to the Skagerrak (Måseskär site) and two to areas neighbouring the Bornholm Basin. An additional cruise concentrating on geological and geochemical investigations was performed in 2002 (Emelyanov & Kravtsov 2004). The expeditions recorded oceanographic data, including CTD profiles and current velocities as well as geochemical data, including heavy metal concentration in sediments. They also had a special focus on total arsenic, which could have originated from the decomposition of arsenic-based chemical warfare agents. Water column analyses included oxygen concentration, pH, reduction potential and phosphorus concentration. In the course of this program, Russia also conducted magnetometric, gradiometric and multibeam surveys on the Bornholm site, which together with ROV (remotely operated vehicle) inspections showed the presence of sunken ships in the dumping area. In 1997, a lump of sulfur mustard was recovered from the Bornholm Deep during the 34th cruise of the RV Professor Shtokman and sent for detailed chemical analysis to a laboratory in St. Petersburg (Paka & Spiridonov 2002).

In the years 1994-2006, Russia performed microbiological studies on sediments from the dumpsites at Bornholm, Gotland and Skagerrak (Medvedeva et al. 2009), to investigate the abundance and degradation capabilities of microorganisms tolerant to sulfur mustard-related hydrolysis products, including thiodiglycol and related organochlorine substances.

Figure 10: A lump of solidified sulfur mustard from a Spray Can 37 mine, evident by the conserved shape (Picture source: Maritime Surveillance Centre South on Bornholm).

2.3.2.1.5 Lithuania

A part of the Gotland Basin dumpsite which is located within the western part of the Lithuanian exclusive economic zone (EEZ) about 70 nautical miles (roughly 130 km) from the Lithuanian coast (on the Klaipėda-Venspilis plateau slope), has been investigated in the frame of national Lithuanian projects. Expeditions in October 2002 (scanning of the dumpsite bottom by the Lithuanian naval vessel 'Kuršis'), June 2003 (chemical weapon dumpsite) and August 2004 (national monitoring stations) were organized by the Ministry of National Defence of the Republic of Lithuania, the Ministry of Environment of the Republic of Lithuania, the Centre of Marine Research (since 2010 the Department of Marine Research of the Environmental Protection Agency) and the Institute of Geology and Geography.

Figure 11: Research in full protection suits on a vessel in the western part of the Lithuanian EEZ, within the dumpsite area of the Gotland Basin in June 2003 (Picture source: G. Garnaga).

The aim was to ascertain if chemical munitions were dumped in the waters of the Lithuanian EEZ and to perform an environmental impact assessment by evaluating the conditions of the environment and biota in the area under investigation. In this regard, hydrological, hydrochemical, biological and sedimentological parameters were investigated (Garnaga & Stankevičius 2005, Garnaga et al. 2006). Arsenic in sediment samples from the chemical munitions dumpsite was assessed together with scientists from the Marine Environment Laboratory and the International Atomic Energy Agency, Monaco (TC project RER/0/016).

A new research project, ‘The application of isotope methods to assess the spreading of organic substances in the Baltic Sea’, began in 2012 and is led by the Lithuanian state funded scientific research institute Centre for Physical Sciences and Technology with the involvement of scientists from the National Environmental Protection Agency and the Nature Research Centre of Lithuania. The main objective of this project is to develop methods based on compound-specific stable isotope and radio-carbon measurements to assess the sources and the circulation of organic pollutants in the studied area, including an assessment of environmental exposure and risk scenarios in the Baltic region caused by chemical warfare materials.

2.3.2.2 International activities

2.3.2.2.1 EU-funded project MERCW

In the years 2005-2008, the dumpsites were studied by the EU FP6 project ‘Modeling of Environmental Risks related to sea-dumped Chemical Weapons’ (MERCW). This project, focusing on the Bornholm dumpsite, aimed to develop a multidisciplinary approach to the problem, ranging from the development of a release and migration model of chemical warfare agents from the dumpsite to an assessment of the environmental threat and development of indices to be used by authorities. To date, MERCW has published a synthesis report of the available data (MERCW 2006) and accompanying scientific publications, most of which are cited in this report (Sanderson et al. 2007-2010, Niiranen et al. 2008, Missiaen & Feller 2008, Medvedeva et al. 2009, Missiaen et al. 2010, Zhurbas et al. 2010).

2.3.2.2.2 EU-funded project CHEMSEA

The ‘Chemical Munitions Search & Assessment’ (CHEMSEA) project is funded by the European Regional Development Fund within the framework of the Baltic Sea Region Program and commenced in 2011. The project concentrates on the Gotland dumpsite as well as dispersed, unverified and unofficial dumps. It continues and expands on the multidisciplinary approach pursued by the MERCW project in order to perform risk assessments of the dumpsites by means of extended surveys, modeling and biomarker approaches. The CHEMSEA project aims at providing risk assessment tools to be used by the maritime administrations of the Baltic countries (Bełdowski & Long 2012).

2.3.2.2.3 NATO SPS-funded project MODUM

The project ‘Towards the Monitoring of Dumped Munitions Threat’ (MODUM) has been submitted as a proposal to the NATO Science for Peace and Security (SPS) program and its evaluation is currently in progress. The project intends to investigate the possibility of using Autonomous and Remotely Operated Underwater Vehicles (AUVs and ROVs) for the creation of a monitoring network for the dumpsites of chemical warfare materials in the Baltic Sea. The international project will utilize the existing research vessels of partner institutions as launch platforms and will cooperate closely with the CHEMSEA project.

2.3.2.3 Corporate activities

2.3.2.3.1 Nord Stream Pipeline Construction

In the context of the construction of the Nord Stream gas pipeline from Russia to Germany by an international consortium, investigations have been conducted on the munitions contamination in the vicinity of the envisaged route and on the potential environmental impacts of the pipe-laying. The pipeline route goes through the known munitions-contaminated areas of the Gotland Deep and the Bornholm Deep, and especially the latter was subject to close inspection. The monitoring program included pre-laying and post-laying investigations and will be continued also after the second pipeline has been completed (Nord Stream AG 2011a-c).

3 Chemical warfare materials dumped in the Baltic Sea

Following World War II (WWII), the U.S., British, French and Soviet authorities reported to have found a total of some 300,000 tonnes of chemical warfare materials in the different occupation zones in Germany (BSH 1993). France has not submitted any official reports on chemical warfare materials found in their occupation zone. The chemical warfare agents were contained in munitions, other storage containers or even in large cisterns. Each of the military authorities dealt with the disposal of captured weapons in different ways in accordance with the Potsdam Agreement in 1945. In general, a small part of the stocks were transferred to the Allies' arsenals, while the bulk quantities were either destroyed and recycled on German territory or dumped at sea. Whereas the U.S. and British authorities dumped chemical warfare materials in areas of the Skagerrak, a large part of the stocks found in the Soviet occupation zone was dumped into the Baltic Sea. Beyond that, even before the end of WWII and also decades after the official conclusion of the demilitarization of Germany, dumping activities of dangerous and obsolete munitions were conducted.

Scope and substance of currently available information

- Currently, in most cases, information on dumping activities originates from contemporary and simplified official summary reports or is based on estimates deduced from official documents or officially documented follow-up accounts. Rarely is gapless and precise information available from the official correspondence that must have accompanied the activities of trafficking chemical warfare materials over land, in harbors and on sea.
- Only a small fraction of the files that were archived have been perused, analyzed, cataloged in detail, made available to the public and accessed by researchers. Furthermore, the efforts to carry out research for historical information on dumping activities have been limited by the resources available for this task. Consequently, the current state of knowledge is based on a foundation of official documents and provides an authentic, but very general, picture of the problem of sea-dumped chemical warfare materials in the Baltic Sea.
- With increasing utilization of the seafloor, and underlined by documented findings of chemical warfare materials outside of the known dumpsites, it needs to be stressed that the benefits of adding detail to the general picture of information would be substantial.

Figure 12: The current state of knowledge and quality of sources.

3.1 Introduction

Dumping of chemical munitions has been carried out for different reasons. Towards the end of the war they were dumped to remove dangerous munitions from areas subject to imminent attacks, to prevent munitions from being seized by attacking troops and to demilitarize before surrender. In the immediate post-war period, dumping at sea was chosen by the Allies to allow for the swift demilitarization and removal of dangerous war materials from Germany. The dumping activities that took place during the last stages of war and the post-war period were conducted under pressure of time, either imposed by the attacking forces or by agreed deadlines. Dumping activities in later years can be seen as a choice of method that is a cheaper and safer compared to land-based disassembly and decontamination procedures.

Figure 13: German sulfur mustard storage site at St. Georgen in May 1945. A U.S. soldier is examining the tiers of chemical warfare agent-filled shells (Picture source: Bureau of Public Relations, War Department, Washington. Kindly provided by T.P. Long).

3.1.1 Dumping activities

In general, the main idea was to dump chemical munitions as far away and as deep as possible. However, this was not always achievable due to the lack of available resources (e.g., obsolete but reasonably sea-worthy ships for scuttling) and tight schedules for demilitarization.

‘Dumping areas’ and ‘Dumpsites’

- In the context of this report, the term ‘dumping area’ describes an area formerly chosen and designated for dumping munitions at sea, e.g, by instructing the ships’ captains to dump in sight of a landmark or moored buoy.
- As described below, dumping of munitions was also occasionally conducted outside of the known and designated dumping areas.
- In contrast to the historical meaning of intended usage, the term ‘dumpsite’ is used to describe the place of actual occurrence of dumped warfare materials. In the context of dumping conventional munitions at sea, it is known that some ‘dumping areas’ never became ‘dumpsites’ due to bad weather thwarting the activities.
- However, a ‘dumpsite’ found today might even be a ‘dumping area’ described in historical documents that have not been found or assessed yet.
- The use of these terms is not necessarily reflected in the descriptions contained in sea charts. While the area south of Little Belt was used as a ‘dumping area’, for example, in contemporary sea charts it is only described as ‘foul (explosives)’ and not as ‘explosives dumping ground’.

Figure 14: Definitions of the terms ‘dumping area’ and ‘dumpsite’.

During the last stages of WWII, the southern entrance to the Little Belt was used by German troops as a reachable dumping area in the Baltic Sea (*cf.* Figure 14). With a depth of about 30 m, it is the shallowest of all dumping sites discussed here. In the post-war period, the Military Administrations in Germany chose deeper basins exceeding water depths of 70 m south-east of Gotland, east of Bornholm and in the Skagerrak for dumping chemical warfare materials. Conventional munitions, on the other hand, were regarded as less problematic and were often dumped closer to the shore (*cf.* Figure 14). Some transports of conventional munitions have been mistaken with transports of chemical munitions: the steamer ‘Bernlef’ exploded and sank on 14 August 1945 while anchoring in the Kattegat off the Danish coast near Gilleleje after an accident occurred while dumping munitions overboard. The British Military Administration commissioned the steamer to carry 1,200 tonnes of depth charges and 250 kg of aircraft bombs that had been stored in Denmark (Wichert 2012). While the ship was listed as having carried chemical materials by some publications (CNS 2009), according to previous researches and investigations only conventional munitions were transported by the ship. This is in agreement with the fact that the intended dumping area had been close to the shore. In addition, there are no indications that chemical warfare materials had been stored in Denmark (Wichert 2012).

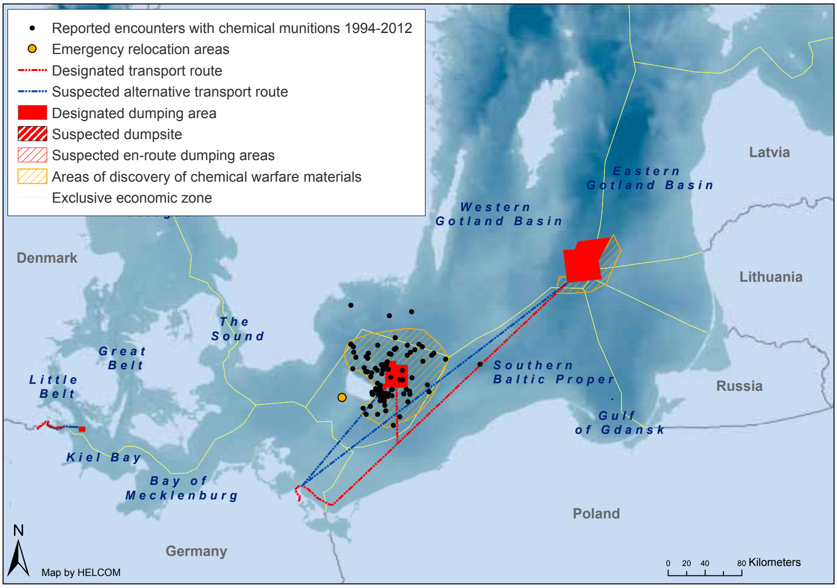


Figure 15: Overview map of known and suspected dumpsites of chemical warfare materials in the Helsinki Convention Area. Reported encounters with chemical warfare materials and emergency relocation areas are also indicated (*cf.* Annex 7.2).

Even after the official conclusion of the demilitarization campaign, chemical warfare materials were discovered on German territory. In the early 1950s, the GDR disposed of these materials by chemical treatment, while in the late 1950s and most decidedly in the first half of the 1960s dumping activities were resumed, mainly by using the old dumping area east of Bornholm. A single transport of Tabun grenades recovered from the harbour basin of Wolgast and then encased in concrete was also shipped to the Norwegian Sea (BSH 1993).

Dumped amounts of chemical warfare materials in the Baltic Sea

- Taking into account the considerations given in Figure 12 and leaving aside information currently available only from single sources (cf. Chapter 3.2), it can be estimated that at least 40,000 tonnes of chemical warfare materials have been dumped in the Baltic Sea.
- The weight of chemical warfare agent mixtures contained can only be adequately estimated if the numbers and types of munitions and bulk containers are known (cf. Table 5, Chapter 3.3.2): Net weight ratios range from low (13-14%, e.g., in grenades) via high (60-75% in large aircraft bombs) to very high percentages in bulk containers (e.g., 900 L containers).
- Also, with regard to the possible inaccuracies of the gross weight numbers, as a general rule of thumb the chemical warfare agent payload of an unknown mixed assortment of chemical warfare materials can be assumed to amount to about 40% of the estimated gross weight.

Figure 16: The amounts of chemical warfare agents dumped in the Baltic Sea and considerations on the net weight of chemical warfare agents' payload contained in the materials.

3.1.2 Modes of dumping

In some cases, warfare materials were loaded in various types of vessels (ships, barges and hulks) which were sunk; in other cases, the warfare materials – munitions (both fuzed and unfuzed) or wooden crates with munitions and bulk containers with chemical warfare agents – were disposed of item-by-item. At the time of dumping, vessels were not equipped with highly sophisticated navigational equipment and might not have been at the predetermined location when being scuttled or did not remain in one place when overboard dumping was carried out in a tedious item-by-item manner. Warfare materials dumped in the latter fashion might then have been spread over a larger area during dumping, either due to drifting vessels or due to floating and drifting of munitions or containers before sinking (see below). These scattered warfare materials are more likely to have subsequently been spread along the sea bed by trawling and might thus become involved in fishing incidents.

The combination of time constraints with the lack of available and expendable ships and the ensuing practice of item-by-item dumping has resulted in *en route* dumping. Officially documented follow-up accounts and the results of official investigations of the People's Police of the GDR in 1953 pertaining to the travel and cargo unloading times in relation to the distances, clearly prove that materials have been thrown overboard well before reaching the intended dumping area and that ships have departed from the target area before dumping had even been completed (Bruchmann 1953, Jäckel 1969). Consequently, chemical warfare materials have been scattered along the transport routes from the harbours to the dumping areas (Flensburg ↔ south of Little Belt; Wolgast ↔ Gotland Basin; Wolgast ↔ Bornholm Basin).

Due to the special sensitivity of chemical warfare materials, chemical munitions of German manufacture were usually stored in special protective storage and transport containers. Unlike conventional grenades, chemical grenades were not stored in six-pack frames, but singularly in non-hermetical wooden (for 10.5 cm grenades) or wicker basket (for 15 cm grenades) encasements, resulting in total transport unit weights of approximately 15 kg and 41 kg, respectively. Chemical bombs were stored in wooden crates, KC50 bombs in twos and KC250 bombs singularly, resulting in total transport unit weights of approximately 130 kg and 210 kg, respectively (Figure 18). In general, the crates were sturdy and well built, sealing the contents off from the environment (Wichert 2012).

Contemporary pictures of expendable ships or hulks being loaded with chemical munitions for British and American dumping runs show munitions stacked in the holds without additional protective storage or transport crates (Figure 17). It needs to be stressed that these vessels were designated for a single scuttling run and were only crewed by a minimum number of personnel.

Figure 17: Chemical munitions and barrels filled with sulfur mustard stacked up on board of the freighter 'Marcy' in Nordenham (Bremerhaven), Germany, under control of the U.S. Military Administration in Germany. The hulk was scuttled in the Skagerrak (HELCOM 2011c).

Due to the low availability of expendable ships or hulks for scuttling, those used were loaded to their maximum capacity, even though this was associated with additional risks during loading. As vessels were an even rarer commodity in the Soviet Occupation Zone, they were required to be re-used and the materials were disposed of item-by-item. Consequently, this required the crew to handle chemical warfare materials both during loading and dumping. With crew safety a priority during transport and dumping, loading the chemical warfare materials with their protective transport cases made sense. Heavy objects undoubtedly had to be stored deep in the ships holds to ensure a stable journey. Accordingly, mostly smaller and lighter objects will have been stored on top and were thus available en route for item-by-item disposal.

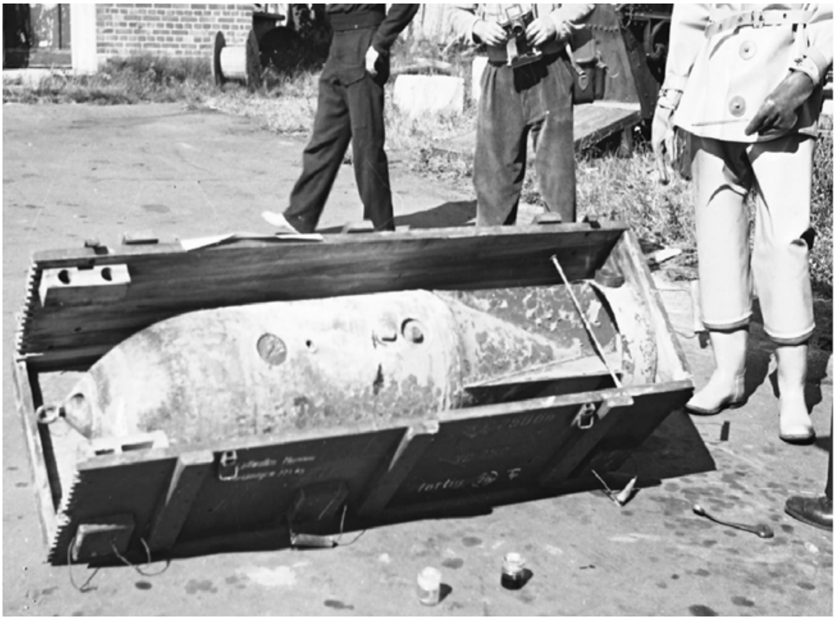


Figure 18: A KC250 aircraft bomb in its wooden storage and transport crate (sides removed and the filling hole of the bomb visible) at Bornholm (Picture source: Bornholm Marinedistrikt).

The overboard item-by-item dumping of grenades could have been carried out by a single person at a relatively high frequency - approximately one per minute. The heavy bomb transport crates, however, would require some additional equipment for overboard disposal such as cranes. This dumping process is also possible when a ship is en route. Indeed, the numerous, pearl chain-like findings of large Fieseler Fi 103 (V1) warheads along the coast of the Flensburg Fjord in the 1950s and1960s could actually be attributed to an en route dumping run in early 1945 as described in an officially documented follow-up account (*cf.* Chapter 3.2.1).

According to officially documented follow-up accounts and reports, the crates would not sink easily and would float and drift for a long time. It was also documented that in some cases, the crates were fired at so that they would fill with water and sink. For the dumping activities under control of the Soviet Military Administration in Germany (*cf.* Chapter 3.2.2 and Chapter 3.2.3), it was reported that following the observation of drifting crates, the bombs were taken out of the crates, disposed of and the crates brought back to the originating harbour of Wolgast for further use (Bruchmann 1953). This procedure is unlikely to have been applied to large KC250 bombs since they are difficult to man-handle and cranes would have been needed to take them out of the crates. With regard to the associated dangers and the additional time this would take, it is likely that KC250 bombs were dumped with their encasements during item-by-item disposal. On the other hand, it can be assumed that it would have been manageable for two men to take a lighter KC50 bomb out of its crate and throw it overboard.

Already during the dumping activities, chemical warfare materials were potentially scattered in the vicinity of the designated dumping areas and well away from them on the transport routes due to the practice of en route dumping. The possibilities for further relocation of sea-dumped chemical warfare materials by natural processes and anthropogenic activities are discussed in Chapter 4.2.

3.2 Areas of concern

The following section describes the areas which are of concern because of documented, possibly detected or suspected presence of dumped chemical warfare and incendiary agents.

3.2.1 South of Little Belt and transport routes from Flensburg

Facts

The southern entrance to the Little Belt is an area that was used by German troops and refugees for munitions disposal during the last days of WWII (Jäckel 1969, BSH 1993, Wichert 2012).

In mid-February 1945, the upper command of the Wehrmacht issued the order to secure the stocks of chemical warfare materials and to move them from areas in danger of being overrun by the Allies. In the following two months, ships and trains - loaded with chemical munitions that had been stored at various facilities - headed for Flensburg. As the Allies advanced until April 1945, the safe storage of the chemical warfare materials became an increasingly difficult task.

Towards the end of April, two barges that had been brought from the munitions factory in Lübbecke to Kiel, loaded with approximately 1,250 tonnes of chemical grenades and crates containing 250 tonnes of powder, were tugged on order of the German Navy to a designated area located at the southern entrance to the Little Belt and scuttled by breaking off rivets. Furthermore, as documented in another official follow-up account, the ships 'Taurus', 'Karoline' and 'Marie Luise' conducted two dumping runs each with chemical warfare materials collected in Flensburg towards the designated

Profile of area south of 'Little Belt'

Area according to current sea charts

- Depth: 25-31 m
- Ground: partly thick layer of mud (0-8 m)
- Size: 4,180 ha

Dumping activities

- April/May 1945, on behalf of the German Navy
- September/October 1945, emergency dumping of leaking materials, under control of the British Military Administration in Germany (uncertain)

Originating harbour

- Flensburg

Amounts dumped (approx.)

- 5,000 tonnes item-by-item (2,000 tonnes payload, est. at 40%)
- 1,250 tonnes on two barges (cargo from barges recovered in 1959/60, payload 143 tonnes Tabun-mixture (DE Ministry for Interior 1960)

Chemical warfare agent types

- Tabun (found by investigations in 1955 & 1959/60 (barges) and 1971/72 (scattered items))
- Sulfur mustard (historical evidence)

Container-types

- Bombs (e.g. KC250), partly in wooden crates
- Grenades (10.5 and 15 cm), fuzed (at least partly)

On-site-dumping

- Item-by-item; not all ships anchored, partly drifting items reported
- Scuttling of two barges

En-route-dumping

- Possibly 1,200 tonnes of munitions dumped en route along the southern part of the Flensburg Fjord

Mixing with other warfare materials

- Yes (based on findings and historical evidence)

Warning in sea charts

- Foul (explosives)
- Anchoring and Fishing dangerous

Catches & accidents

- No official reports

dumping area, beginning at the end of April and continuing through to the first days of May. In 1961, the former captain of the 'Taurus' testified that during these runs, altogether some 5,000 tonnes of chemical bombs and shells were dumped in the area by item-by-item disposal. While his ship had been anchored during the dumping, he could not vouch for the other ships. It was also reported that, during the first run, the bombs, which were housed in wooden crates, were seen to be drifting for a long time before sinking after having been thrown overboard. In follow-up runs, the practice was changed and the crates and bombs were allegedly disposed of separately. The participants of the disposal runs reported that manual item-by-item disposal was also conducted en route from Flensburg to the dumping area. Taking into account the demands for fuel conservation and that harbour books show that it took less than 24 hours, it can be assumed that a cargo of at least 1,200 tonnes of chemical warfare materials was dumped in the Flensburg Fjord. Indeed, it was reported by a participant of one of these runs that about 200 sulfur mustard shells were thrown overboard after the ship had passed the Ochseninseln (Danish: Okseøer). Due to the constrictions posed upon ships with regard to mine-free routes, the necessity of secrecy and the wartime dangers of the Danish coast, the route taken by the ships was likely to have been close to the German coast (Wichert 2012).

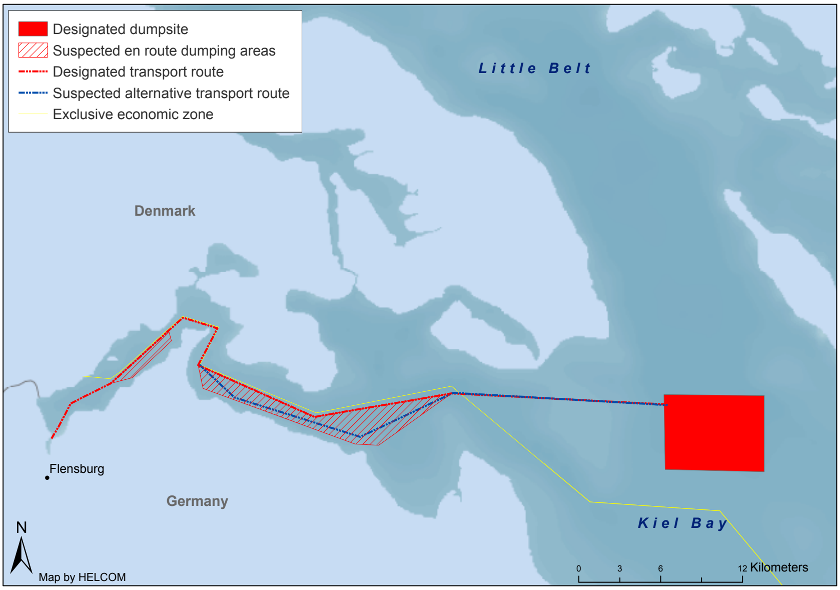


Figure 19: Map of the dumpsite south of Little Belt designated in sea charts; the suspected former transport route; and areas suspected to be contaminated by chemical warfare materials dumped en route.

This historical information on practiced en route dumping is also in line with Fieseler Fi 103 (syn. V1) cruise missiles or their parts being found along the coast of the Flensburg Fjord in the 1950s and 1960s. It was reported that 600 tonnes (approximately 250 items) of these large munitions had been dumped during an additional run as part of the same dumping operation described above, while headed for the designated dumping area south of the Little Belt. Furthermore, at the end of the war the same area served as a rally point for navy and refugee vessels which, in all probability, conducted disarmament by overboard dumping on the orders of the Allies. After the war, the harbour of Flensburg, under control of the British Military Administration in Germany, was also used for loading of vessels with chemical warfare materials destined for scuttling in the Skagerrak. Contemporary documents describe the occurrence of two incidents with leaking materials having arrived by train. One document describing an incident with sulfur mustard munitions explicitly stated the orders given by the port control officer to load the munitions on a barge and throwing them overboard in the dumping area designated for Flensburg. It is uncertain if the area meant was that south of Little Belt and whether the order was carried out as issued.

Figure 20: Leaking chemical munitions were sometimes encountered during the trafficking of chemical warfare materials for sea-dumping. This item, leaking sulfur mustard, was encountered during handling in Bremerhaven under control of the U.S. Military Administration in Germany. It was reported to have been decontaminated later. Another general option to cope with such dangerous items was emergency sea-dumping (HELCOM 2011c).

The wreck of the larger (1,000 tonnes) of the two scuttled barges with chemical munitions was discovered in the area in 1955 by fishermen. Investigations carried out by Schleswig-Holstein's explosive ordnance disposal (EOD) service discovered that the cargo were not high-explosive grenades as initially suspected, but fuzed 10.5 and 15 cm shells filled with the nerve agent Tabun. Further investigations by the police pertaining to the origins and historical background of the dumped materials were carried out and revealed that the wreck of the smaller barge (500 tonnes) was lying nearby. Following extensive preparations in 1959-1960, the barges were lifted, brought to shallower waters and the chemical munitions and crates of powder on them were recovered. Altogether, 69,075 shells weighing about 1,250 tonnes (59,056 of 10.5 cm and 10,019 of 15 cm shells) were recovered, set in concrete blocks and re-located to the Bay of Biscay.

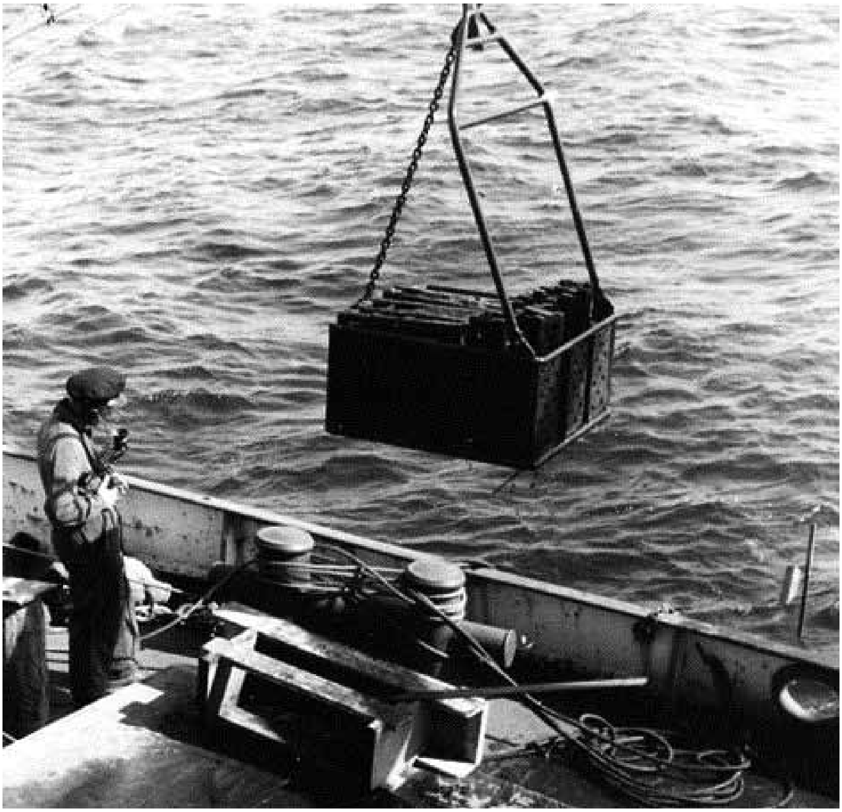


Figure 21: A basket filled with 10.5 cm Tabun shells is heaved on board from the wreck of the 1,000 tonnes barge in 1959/1960, which had been scuttled on behalf of the Germany Navy before the end of the war in 1945 (Kinder 1960).

In 1971/1972, the type and state of scattered chemical munitions in the area south of Little Belt was investigated. A total of 65 bombs and shells were raised from the mud for inspection and to identify their contents. The bombs were heavily corroded and no longer contained any chemical warfare agents. The divers also found bombs in wooden crates. In contemporary reports, the assumption was expressed that, based on visual inspection, the heavy corrosion of the empty hulls might be attributed to a former phosgene content. However, as neither historical nor chemical proof exists, the presence of phosgene is purely speculative. Even so, three recovered grenades were tested and revealed remaining Tabun contents of about 0.1, 0.6 (15 cm shells) and 72% (10.5 cm shell), respectively (weight percentage; expected original filling contents: 80% Tabun, 20% chlorobenzene). The grenade with the highest Tabun content was leaking from the seal where it was filled. Other bombs lifted, but not subjected to laboratory tests, were also ascribed to have been filled with Tabun.

None of the sulfur mustard shells which have been indicated by newly appraised official documents of follow-up accounts as 'dumped' in an area located at the southern entrance to the Little Belt and on the transport route from Flensburg have been found to date. Further investigations on the matter of en route dumping in the Flensburg Fjord and the possibility of sulfur mustard warfare material disposal in the area are presently being conducted by Germany.

Sediments

In general, the water in the area is around 25-31 m deep and the seafloor is in most places characterized by a thick layer of soft and muddy sediment (0-8 m). The rate of sedimentation in this area can be estimated up to 1-2 mm/year, resulting in a muddy sediment layer of up to 13 cm since 1945. The dumpsite is included on sea charts as an area encompassing around 4,180 ha and is designated as 'foul (explosives)' and dangerous for anchoring and fishing. Although the area is used for fishing, no accidents with chemical munitions have been officially documented.[1]

New knowledge and findings

Recently found historical documents and the review of incident reports of the Schleswig-Holstein bomb disposal service from 1955 to 1970 have led to the conclusion that there were also dumping activities under German command towards the end of the war. Large amounts of conventional munitions, including at least some 200 artillery shells with mustard gas, were dumped item-by-item between Flensburg port and the Kalkgrund lighthouse.

According to reviewed investigation reports, there is no information to support the claim of the 1994 CHEMU report that sea-dumped munitions in the Little Belt area contained the chemical warfare agent phosgene (*cf.* Chapter 7.1.6).

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[1] In the German TV current affairs programme 'Panorama' aired on 3 August 1970, the leader of the Danish Army's School for Warfare Agents, Major Andreassen, stated that two accidents are known to have occurred in the area. However, this information could not be verified.

3.2.2 Gotland Basin and transport routes from Wolgast

Facts

The southern part of the Gotland Basin, located south-east of Gotland and south-west of Liepāja, was the area initially designated for dumping chemical warfare material on the orders of the Soviet Military Administration in Germany (Bruchmann 1953, Jäckel 1969, BSH 1993). It was later displaced by a new dumping area designated in the Bornholm Basin.

Ships from the British occupation zone were commissioned and between May and September 1947 an alleged 2,000 tonnes of chemical warfare materials (consisting of approximately 1,000 tonnes of chemical warfare agent payload) were shipped by the 'Elbing IV' and 'Elbing VIII' from the loading port of Wolgast to this area and dumped there by item-by-item disposal. Ships did not anchor on spot and may have drifted while dumping the materials. It was also reported that the bombs were thrown overboard inside the wooden crates, which drifted before sinking.

Moreover, during later dumping runs to the Bornholm Basin, chemical warfare materials were thrown overboard while the ships were en route. It is unclear whether this practice was also used during the initial dumping runs to the Gotland Basin. While the position designated for the dumping area is known, the actual position of the munitions is uncertain due to drifting ships and

Profile of 'Gotland Basin'

Area according to current sea charts

- Depth: 93-137 m
- Ground: mostly thick layer of clayey mud (0-6 m)
- Size: 141,610 ha

Dumping activities

- May – September 1947, on behalf of the Soviet Military Administration in Germany

Originating harbour

- Wolgast

Amounts dumped (approx.)

- 2,000 tonnes item-by-item (1,000 tonnes payload)

Chemical warfare agent types

- Sulfur mustard
- Clark-types / arsine oil
- Adamsite
- α-chloroacetophenone
- Tabun (suspected, found in Wolgast harbour)

Container-types

- Bombs, partly in wooden crates
- Grenades
- Bulk containers

On-site-dumping

- Item-by-item; ships not anchored, partly drifting items reported
- En-route-dumping
- Possible

Mixing with other warfare materials

- Co-dumping of conventional munitions and occurrence of sea mines
- Chemical waste (hydrogen cyanide)

Warning in sea charts

- Explosives Dumping Ground
- Anchoring and Fishing dangerous

Catches & accidents

- Yes

crates, and possible relocation by bottom-trawling. High explosive bombs were among the materials dumped in the area and the existence of sea mines from the war was recently confirmed by the CHEMSEA project (further information will be available after completion of the project).

The Gotland Basin area is currently being investigated within the framework of the CHEMSEA project (*cf.* Chapter 2.3.2.2.2). Previous microbiological research revealed that while the total quantity and numbers of saprophyte bacteria were typical for the Baltic Sea environment (Garnaga & Stankevičius 2005), especially the occurrence of bacteria tolerant to sulfur mustard hydrolysis products was elevated in comparison to a reference site (*cf.* Chapter 4.4.2).

Table 1: Payload weights and containers of chemical warfare materials previously reported to have been dumped in the wider area of the Gotland Basin on behalf of the Soviet Military Administration in Germany between May and September 1947 (HELCOM 1994). *In addition, the dumping of 27 tonnes of high-explosive bombs and six tonnes of smoke grenades was reported. With respect to the almost identical distribution of container types and chemical warfare agents reported for the materials shipped off to the Bornholm Basin (cf.* Table 2), *it should be noted that summary information has been converted back to detailed numbers.*

	Chemical warfare agent payload (Overall weight given in tonnes)						
Container types	**Sulfur mustard**	**Clark-types**	**Adamsite**	**CAP****	**Other*****	**Total**	**Ratio**
Aircraft bombs	512	78	51	41		682	73.7%
Artillery shells	58		5	3		66	7.1%
Mines*	4					4	0.4%
Encasements	7	18	60		6	91	9.8%
Containers		80				80	8.6%
Drums			2			2	0.2%
Total	**581**	**176**	**118**	**44**	**6**	**925**	
Ratio	***62.8%***	***19.0%***	***12.8%***	***4.8%***	***0.6%***		

** Mines = Spray Can 37 (‘Sprühbüchse 37’);*
*** CAP = α-chloroacetophenone;*
**** Other = hydrogen cyanide (‘Zyklon B’, chemical waste).*

Sediments

In general, the water depth in the large area marked on sea charts as ‘explosives dumping ground’ ranges between 93 m and more than 120 m. The thickness of the sediments reaches 4-6 m, with clayey muds prevailing. The sedimentation rate is also low, varying between 0.5 to 1 mm per year and resulting in an additional layer of up to 6 cm since 1948 (MERCW 2006). Incidents where fishermen have caught chemical warfare material have occurred in the area before 1994 with encounters of sulfur mustard, Clark and α-chloroacetophenone materials (*cf.* Annex 7.2). This is reflected on sea charts, advising that fishing and anchoring is dangerous in the area.

New knowledge and findings
The overall observation can be made that the distribution of munitions in the Gotland Basin is broader than earlier estimated, that it is not a primary dumpsite, but objects are quite evenly distributed in the area.

Recent results from scientific research performed by Lithuania (*cf.* Chapter 2.3.2.1.5) on contaminants in the sediments and their effects on biota are included in this report.

3.2.3 Waters around Bornholm

In this sub-chapter, the facts are described in more detail, divided according to the different dumping operations - by relating to specific incident reports and providing evidence for *en route* dumping.

Profile of 'Bornholm Basin' area

Area according to current sea charts
- Depth: 93-137 m
- Ground: mostly thick layer of clayey mud (0-6 m)
- Size: 67,260 ha

Dumping activities
- August 1945 - December 1946, on behalf of the British Military Administration in Germany (based on single source)
- August 1947 – January 1948, on behalf of the Soviet Military Administration in Germany (major activities)
- 1959 – July 1965, on behalf of GDR authorities

Originating harbours
- British activities: Hamburg, Kiel, Lübeck
- Soviet activities: Wolgast
- GDR activities: Wolgast, Peenemünde, Karlshagen

Amounts dumped (approx.)
- 32,000 tonnes item-by-item (Soviet activities, 11,000 tonnes payload)
- 30 tonnes item-by-item (GDR activities)
- 30 tonnes on scuttled hulk (GDR, 1962)

Chemical warfare agent types
- Sulfur mustard (no evidence for nitrogen mustard)
- Clark-types / arsine oil
- Adamsite
- α-chloroacetophenone
- Phosgene (only GDR transports)
- Lewisite (found in on-site investigations)
- Tabun (suspected, found in Wolgast harbour)

Table continues ->

3.2.3.1 Bornholm Basin and transport routes from Wolgast

Facts
The southern part of the Bornholm Basin, located to the east off Bornholm, is the main site used for chemical munitions disposal in the Baltic Sea during the post-war dumping activities on orders of the Soviet Military Administration in Germany (Bruchmann 1953, Jäckel 1969, BSH 1993).

After initial dumping runs had been aimed at the Gotland Basin, beginning in August 1947, more ships from the British and American occupation zones were commissioned ('Brake', 'Odermünde', 'Christian', 'Jupiter', 'Venus' and 'Rhein'). With the lease for the 'Elbing IV' and 'Elbing VIII' expiring in September, August 1947 supposedly marks the

Table continues from previous page

Container-types	• Bombs, partly in wooden crates • Grenades • Bulk containers • Spray cans • Wooden crates
On-site-dumping	• Item-by-item; ships not anchored, partly drifting items reported (Soviet activities) • Scuttling of vessels (GDR, British activities)
En-route-dumping	• Yes (Soviet activities)
Mixing with other warfare materials	• Co-dumping of conventional munitions • Chemical waste (hydrogen cyanide)
Warning in sea charts	• Explosives Dumping Ground (sometimes referred to as ‘extended dumpsite’) • Anchoring and Fishing dangerous • Gas munitions (for circular area of formerly designated dumping in the north-eastern part of the Explosives Dumping Ground; sometimes referred to as ‘primary dumpsite’)
Catches & accidents	• Yes

turning point when the lengthy trip to the Gotland Basin was replaced by a shorter journey to a new designated dumping area off Bornholm. The dumping area - sometimes referred to today as the ‘primary dumpsite’ - was located approximately at 55° 20’ N, 15° 37’ E (WGS84), in the northern part of the area that is currently marked as ‘larger explosives dumping ground’ on sea charts. Between August 1947 and January 1948, an alleged 32,000 tonnes of chemical warfare materials, later reported to have contained altogether about 11,000 tonnes of chemical warfare agent payload, were shipped to the area (*cf.* Table 2).

A variety of different chemical warfare materials were dumped in the course of this operation. While wooden or metallic encasements were also used, more than 80% of the dumped chemical warfare materials were munitions containing explosives, with large KC50 and KC250 aircraft bombs forming the largest contingent. Dumping was carried out by item-by-item disposal and the wooden crates were often seen drifting before sinking. Crates were also known to have been washed ashore, and to avoid this, in some cases, orders were given to fire upon the crates (Sanderson & Fauser 2008). It was reported that in other cases, the bombs were taken out of the crates, disposed of and the crates brought back to the originating harbour of Wolgast for further use (Bruchmann 1953).

Table 2: Payload weights and containers of chemical warfare materials previously reported to have been dumped in the wider area of the Bornholm Basin on behalf of the Soviet Military Administration in Germany between May and September 1947 (HELCOM 1994). *In addition, the dumping of 314 tonnes of high-explosive bombs and 65 tonnes of smoke grenades was reported. With respect to the almost identical distribution of container types and chemical warfare agents reported for the materials shipped off to the Gotland Basin* (*cf.* Table 1), *it should be noted that summary information was converted back to detailed numbers.*

	Chemical warfare agent payload (Overall weight given in tonnes)						
Container types	**Sulfur mustard**	**Clark-types**	**Adamsite**	**CAP****	**Other*****	**Total**	**Ratio**
Aircraft bombs	5,920	906	591	479		7,896	73.8%
Artillery shells	671		61	36		768	7.2%
Mines*	42					42	0.4%
Encasements	80	203	693		74	1,050	9.8%
Containers		924				924	8.6%
Drums			18			18	0.2%
Total	**6,713**	**2,033**	**1,363**	**515**	**74**	**10,698**	
Ratio	***62.8%***	***19.0%***	***12.7%***	***4.8%***	***0.7%***		

** Mines = Spray Can 37 (‘Sprühbüchse 37’);*
*** CAP = α-chloroacetophenone;*
**** Other = hydrogen cyanide (‘Zyklon B’, chemical waste).*

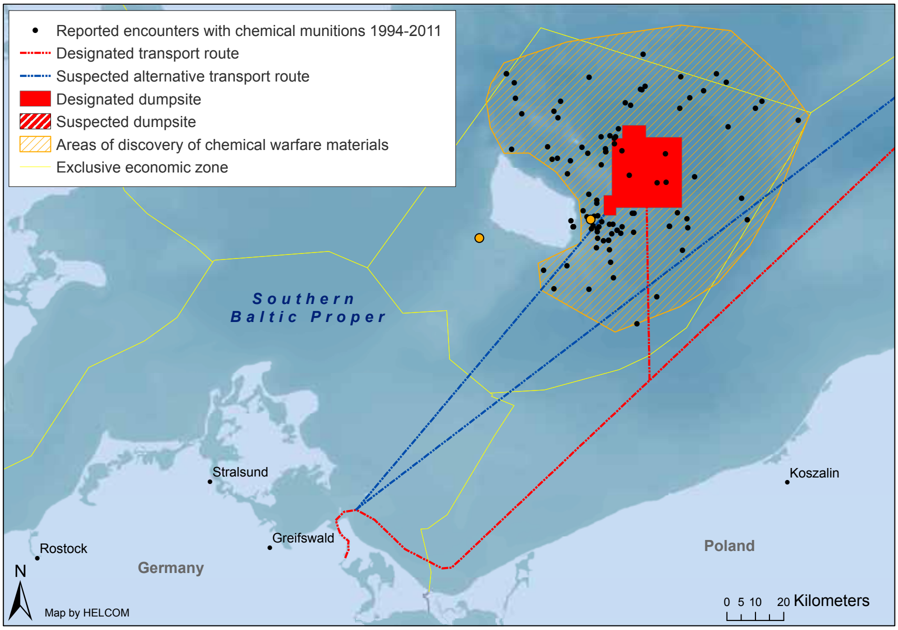


Figure 22: Map of the ‘extended dumpsite’ east of Bornholm designated on sea charts and (suspected) former transport routes from the loading port of Wolgast. Reported encounters with chemical warfare materials and emergency relocation areas are also indicated (*cf.* Annex 7.2).

Even after the official conclusion of the demilitarization campaign conducted under control of Soviet Military Administration, chemical warfare materials were discovered on the territory of the GDR. Some materials were found in former military facilities, others were recovered from the harbour basin of Wolgast where the trafficking of these materials had been carried out. The discovery of materials with sulfur mustard, Clark I, Adamsite, α-chloroacetophenone and Tabun in the harbour basin of Wolgast in 1952/1953 and 1964/1965 can be assumed to reflect the types of chemical warfare agents dumped under the control of Soviet Military Administration in the Bornholm and Gotland basins. However, the nerve agent Tabun has not been reported to have been among the materials disposed of under control of the Soviet Military Administration (*cf.* Table 1 and Table 2), nor has it been found or detected in the dumpsites. Although apparently handled in Wolgast harbour, these materials might have been shipped elsewhere.

GDR dumping

1959 - one transport with 12 tonnes of bombs with sulfur mustard

1960 - one transport with 10 tonnes of bombs with sulfur mustard and phosgene bottles

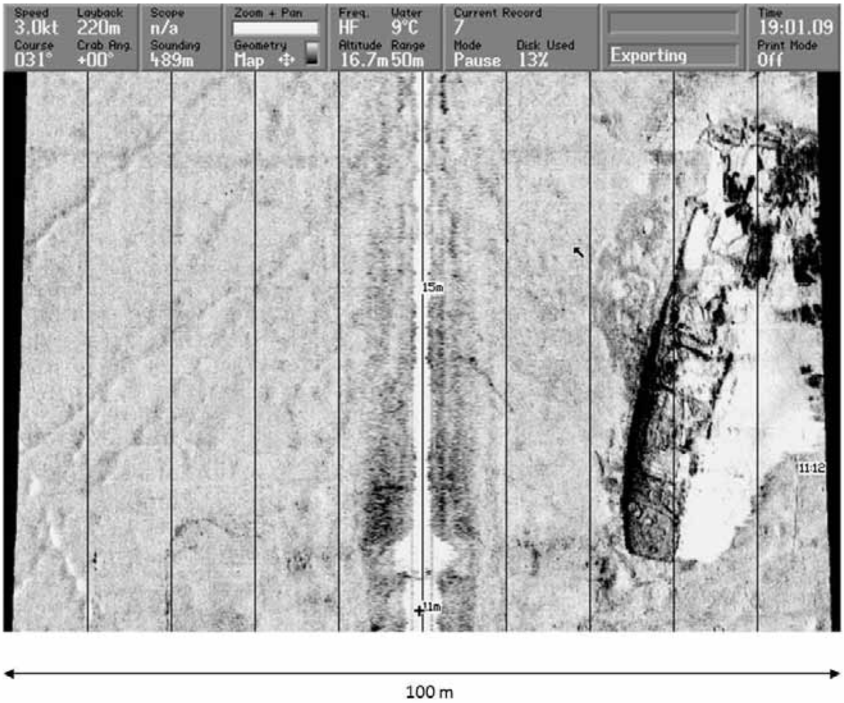
1962 - one transport with 193 bombs with sulfur mustard and phosgene, 78 bottles with phosgene, 3 tonnes of Adamsite, 1 barrel with phosgene, 1 barrel with sulfur mustard, 7 barrels with smoke-generating agents (materials covered in concrete on the hulk ‘Hanno’, sunk by detonation on site)

1963 - one transport with 24 bombs with phosgene
1965 - one transport with 33 grenades with sulfur mustard, 65 grenades with chloroacetophenone, 1 bomb with sulfur mustard

Figure 23: Reported dumping activities with involvement of GDR explosive ordnance disposal teams.

An official summary report by the GDR explosive ordnance disposal (EOD) teams in June 1967 states that they conducted seven transports between 1953 and 1965. As evident in the original documents that the summary report must have been based on, the transports conducted in 1953 were not dumping runs. More specifically, they encompassed materials recovered from Wolgast harbour, which were brought to the destruction facility in Kapen. In addition, the offshore item-by-item dumping of chemical warfare materials and a single scuttling run by the GDR EOD teams were carried out between 1959 and 1965 (*cf.* Figure 23) from the ports of Wolgast, Peenemünde and Karlshagen. The dumping runs were described to have been aimed at the dumping area east of Bornholm and involved some 60 tonnes of chemical warfare materials (bombs, shells and other containers filled with sulfur mustard, phosgene, Adamsite and Clark). It was previously estimated that after 1952, about 200-300 tonnes of chemical warfare materials were discovered on GDR territory and dumped in the Baltic Sea (BSH 1993). Taking into account the information provided by single sources for dumping south-west of Bornholm (*cf.* Chapter 3.2.3.2), the dumping referred to by sources might have amounted to approximately 120 tonnes, while other materials might have been destroyed in onshore destruction facilities.

Investigations carried out between 1999 and 2006 detected four apparently metallic, heavily damaged shipwrecks, often deeply immersed in bottom sediments, in the area of the ‘primary dumpsite’ designated for dumping activities under the control of the Soviet Military Administration (Figure 24). Apparent munitions objects were found on the decks or in the immediate vicinity of some of the wrecks (Missiaen et al. 2010). To date, the origin and contents (chemical or conventional warfare materials or other cargo) of the shipwrecks discovered in the formerly designated dumping area remain unclear.



Speed 3.0kt
Layback 220m
Course 031°
Crab Ang. +00°
Scope n/a
Sounding 489m
Zoom + Pan
Geometry Map
Freq. HF
Water 9°C
Altitude 16.7m
Range 50m
Current Record 7
Mode Pause
Disk Used 13%
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Time 19:01.09
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Figure 24: Side-scan sonar picture of a wreck (length 55m, width 10m, elevation above bottom < 4m) in the primary dumpsite, in the Bornholm Basin at 55° 18.58’ N, 15° 38.27’ E. Three other wrecks were found at 55° 19.03’ N, 15° 37.56’ E; 55° 19.00’ N,15° 37.67’ E and 55° 18.10’ N, 15° 35.48’ E (MERCW 2006; personal communication, V. Paka).

Consequently, at least 32,000 tonnes of chemical warfare materials should be taken into account for this dumpsite. Moreover, it cannot be excluded that conventional munitions may be found among the discarded munitions in the area.

In order to investigate the occurrence of items that were possibly scattered due to en route dumping, part of the former transport routes to the dumping areas in the Bornholm and Gotland Basins lying in the Pomeranian bay in the German EEZ were investigated between 1994 and 1997 (Schulz-Ohlberg et al. 2002) (*cf.* Chapter 2.3.2.1.2). The grid of sonar and magnetometer measurements was potentially dense enough to find large objects or piles of small objects. The conclusion was that only four out of some 100 objects found on the seafloor are still suspected of being corroded remains of munitions. The request to further investigate these four objects has been forwarded to the German Navy. Another 130 iron objects have been detected below the sea bottom. Many of these objects are located in the shallow Oderbank; however, their type and origin still remain unclear.

The area between the 'extended dumpsite' and Bornholm has been used for laying the Nord Stream pipeline in the Danish EEZ. Four chemical KC250 sulfur mustard aircraft bombs and one tail section of such a bomb were discovered in the vicinity (7-17 m distance) of the planned pipeline route during preparatory examinations. They were closely inspected immediately before the pipe was laid in autumn/winter 2010 and re-checked in January 2011 after the pipe laying had been completed (Nord Stream AG 2011a). The bombs were heavily corroded - the outer hulls had been breached and in one case it had almost disintegrated completely. In all cases, the central tube containing a bursting charge with up to 15 kg of TNT was visible and appeared to be intact. Lumps of sulfur mustard were visible in the vicinity of the four bombs and were estimated to have a maximum of 20 kg of agent per bomb (20% of the original filling). Apart from some differences in sediment cover, Nord Stream reported that none of the objects had been disturbed during the laying of the pipeline. According to the Nord Stream report 'Results of Environmental and Social Monitoring' (Nord Stream AG 2011b), there were no other cases of chemical munitions finds along the route of the pipeline (crossing the EEZs of Germany, Denmark, Sweden, Finland and Russia).

The Bornholm Basin and the adjacent areas have been investigated for the presence of chemical warfare agents and breakdown products within the framework of the MERCW project and during the construction of the Nord Stream pipeline. Samples of sediment, pore water and near-bottom water were analyzed in the course of the MERCW project (Missiaen et al. 2010). No chemical warfare agents (sulfur mustard, α-chloroacetophenone, Clark I, Adamsite or arsine oil components) or respective degradation products were detected in the samples of near-bottom water. A single sediment sample contained the stable component Triphenylarsine, a parent compound related to the chemical warfare agent mixture arsine oil. In four samples of pore water and 56 sediment samples out of a total of 59 samples, degradation products of chemical warfare agents were detected. No sulfur mustard was found in the sediments despite the indication of its presence by reported catches of the material and results of microbiological methods: the occurrence of bacteria tolerant to sulfur mustard hydrolysis products was elevated in comparison to a reference site (*cf.* Chapter 4.4.2). In most samples, compounds related to arsenic-containing chemical warfare agents were found. The authors noted that Adamsite and arsine oil appeared to have spread the most and could be detected even outside the designated 'extended dumpsite'. This is in accordance with the findings of Nord Stream (Nord Stream AG 2011c) that compounds derived from arsenic-containing chemical warfare agents could be detected at sampling stations along the pipeline track, outside of the ‘extended dumpsite’, in concentrations of up to 306 µg/kg dry weight sediment, which is 6% of the maximum concentration found in the centre of the ‘primary dumpsite’. Surprisingly, a distinctive derivative compound of weapons-grade Lewisite was detected in sediments in trace and quantifiable amounts during the investigations conducted on behalf of Nord Stream (Nord Stream AG 2011c). The origin of the material is unclear, especially since there is currently no credible evidence that Lewisite had been stockpiled by Germany (*cf.* Annex 7.1 Lewisite) (Vilensky & Sinish 2004).

Sediments

The boundaries of the ‘primary dumpsite’ describe a circular area with a diameter of six nautical miles. The boundaries of the ‘extended dumpsite’ were introduced in 1993 based on positions compiled from several reports and encompass a much larger area with water depths ranging from between 70 m and 105 m (BSH, 1993). Nautical charts warned that anchoring and fishing is dangerous in the area. Geophysical surveys have determined that almost all objects in the primary dumpsite are buried in the seafloor. While the sediment cover on top of some objects reaches a thickness of up to two meters, more than 80% of all objects are buried under a cover of less than 70 cm. This observation is attributed to the very soft muddy sediments in the area into which the objects will have sunk, rather than the low sedimentation rates known to exist in the Bornholm Basin (Missiaen et al. 2010). Fishing incidents with sulfur mustard, Clark and α-chloroacetophenone materials have been reported in an even larger area around the ‘extended dumpsite’, especially westwards of the dumpsite towards the island of Bornholm (*cf.* Annex 7.2).

New knowledge and findings

The types and amounts of chemical warfare agents and their degradation products in the sediments reported by CHEMU were partly confirmed by measurements in the primary dumpsite and its vicinity.

New data on actual measurements on the slope of the Bornholm Deep dumpsite were obtained through environmental monitoring of the Nord Stream pipeline carried out in 2010-2011.

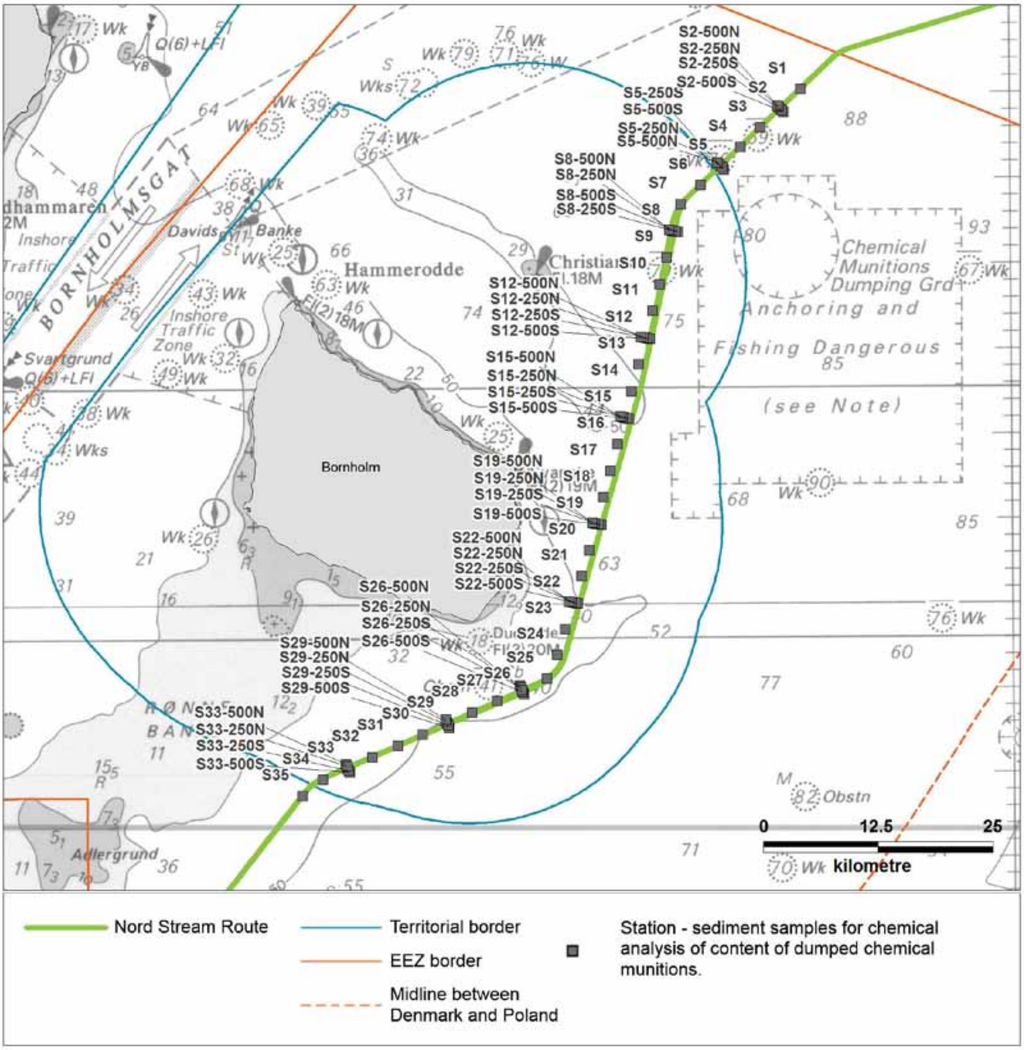

Figure 25: Map of the sampling stations where measurements have been taken within the Nord Stream environmental monitoring (Nord Stream AG 2009).

In the MERCW project, 63 sample points were visited in February 2008, collecting 61 sediments samples and water samples from as close to the bottom as possible (20 cm above the seafloor). The samples were analysed by the Finnish Institute for Verification of the Chemical Weapons Convention, VERIFIN. No parent of degradation products was found from near bottom water and TPA was the only compound found in the sediment samples. Two degradation products were found in porewater samples. As evident from standard deviations, there was significant patchiness in the concentrations found (Sanderson et al. 2010).

Table 3: Summary of MERCW findings (Sanderson et al., 2010). *MCB – Monochlorobenzene; TPA – Triphenylarsine; TCA-deg –Tripropyl arsonotrithioite; DA-deg – degradation product of Clark I; TDG-ox – Thiodiglycol sulfoxide; DM-ox – 5;10-Dihydropheno-arsazin-10-ol 10-oxide; PDCA-ox – Phenylarsonic acid; PDA - Phenyldichloroarsine*

Compound	Mean mg/kg sediment (±SD)	Detection frequency	Porewater Mean ml/L
MCB	1.5 (6)	19%	ND
TPA	1,873 (11,175)	31%	ND
TCA-deg	10 (76)	1%	ND
DA-deg	990 (4,700)	44%	ND
TDG-ox	0.01 (0.01)	1%	ND
DA-ox	240 (1,367)	49%	27 (202) (5%)
DM-ox	35 (79)	60%	ND
PDCA-ox	361 (1,660)	70%	13 (69) (5%)

Table 4: Summary of the measurements from Nord Stream environmental monitoring (2008-2011). *MCB – Monochlorobenzene; TPA – Triphenylarsine; TCA-deg –Tripropyl arsonotrithioite; DA-deg – degradation product of Clark I; TDG-ox – Thiodiglycol sulfoxide; DM-ox – 5;10-Dihydropheno-arsazin-10-ol 10-oxide; PDCA-ox – Phenylarsonic acid; PDA - Phenyldichloroarsine*

Compound	Mean mg/kg sediment (±SD)	Detection frequency (%)	Porewater Mean ml/L (%)
Adamsite	32 (74)	3.5%	ND
Clark I	16 (12)	19.5%	2 (27%)
TPA	10 (5)	2.5%	2 (18%)
PDA	36 (89)	26%	2 (18%)
TCA	19 (23)	12.5%	2 (27%)
Lewisite-ox	15 (5)	2%	ND
PDCA-deg	306 (24)	2%	ND

This study comprised 192 samples assessed for 29 chemical targets analysed by VERIFIN. PDA and TCA were found, as well as parent compounds.[2] In the MERCW findings, lower exposure was observed outside compared to inside the primary dumpsite (Sanderson et al. 2012).

3.2.3.2 The Adlergrund

According to a report by BSH, the areas of the Rønne Bank and the Adlergrund, roughly half-way between Bornholm and Rügen, have been used for dumping munitions in 1946 and later by the People's Navy of the GDR (BSH 1993). The information is mostly based on officially documented follow-up accounts recorded in the course of investigations in 1992 (Schiffner & Nowak 1992).

Documented by official correspondence, it becomes evident that GDR authorities discussed in late 1952 and early 1953 whether chemical warfare materials had been dumped on behalf of the Soviet Military Administration in Germany north-east of Bornholm or in the area of the Adlergrund, south-west of Bornholm (Bruchmann 1953). However, according to officially documented follow-up accounts and archival documents discussed below, it is possible that the area of the Adlergrund was used for scuttling vessels laden with munitions in the late 1950s.

Profile for 'the Adlergrund'

Area in general
- No special area designated in sea charts
- Depth: 5-40 m
- Ground: mostly stones and gravel (Adlergrund)

Dumping activities
- 1956 – 1959, on behalf of GDR authorities (based on single sources)

Originating harbours
- GDR activities: Wolgast, Peenemünde, Karlshagen

Amounts dumped (approx.)
- 60 tonnes scuttled on 5-6 ships (GDR activities, based on single sources)

Chemical warfare agent types
- Mixed munitions

Warning in sea charts
- No warnings pertaining to munitions

Catches & accidents
- No official reports

A participant in disposal activities testified in 1992 that in the second half of 1956, four decommissioned black coastal patrol vessels ('schwarze KS-Boote') were loaded in Wolgast with munitions that had been recovered from the 'Peene' (Schiffner & Nowak 1992). It is unclear whether he was referring to the river Peene or the estuary between the former loading port of Wolgast and Peenemünde, often referred to as Peenestrom. Whether the munitions loaded onto the hulks were at least partly chemical munitions is unknown. Taking the size of the coastal patrol vessels into consideration (length about 26 m), it was later estimated by

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[2] Adamsite – 2008. It was found when VERIFIN was not clear about the method and therefore it is possible that it could have been a degradation product that was measured.

the interviewers that the hulks might have been loaded with some 50 tonnes of materials. The witness, working in the navigational department on board a minelaying and minesweeping ship, stated that the hulks were later towed by such vessels ('MLR-Schiffe') to Saßnitz and then to a dumping area bordering the Bornholm territorial waters, on a line between Saßnitz and Rønne and at a depth 20-30 m. He reported that the vessels were fired upon for scuttling: two exploded while two others lingered for two days before sinking.

A single source describes that on 28 March 1957, an old minesweeping vessel ('R-Boot') of type R-218 loaded with chemical munitions has been scuttled in the Adlergrund (Röseberg 2002). An excerpt from the chronicle of the salvage and rescue service of the People's Navy contained in German federal archives mentions that the diving team scuttled an old minesweeping vessel ('R-Boot') loaded with chemical warfare agents south of Bornholm in 1959 using Tug A14 (BSH 1993). This incident potentially overlaps with the transport of 12 tonnes of bombs with sulfur mustard in 1959, briefly mentioned in an official summary report dated June 1967, on the activities of the GDR's explosive ordnance disposal service. It is unclear whether these three incidents are a single scuttling run attributed to different dates by different sources or three separate activities.

In general, the water in the area is around 5-40 m deep and the seafloor is in most places characterized by stones and gravel. Because of this low depth and stony ground, the Adlergrund is marked on sea charts as foul ground. Some parts of the area are used for sediment and gravel extraction. To date, no findings or incidents with chemical munitions or wrecks have been officially documented. The investigative report of 1992 came to the conclusion that with a high likelihood no larger amounts of munitions have been dumped in the area of the Adlergrund (Schiffner & Nowak 1992).

In summary, the current knowledge on the possible dumping of chemical warfare materials south-west of Bornholm is unsubstantiated and limited to historical information gained from single sources. However, chemical warfare materials can be found south-west of Bornholm in an emergency relocation area (see below), but this is some distance from the Adlergrund.

New information and knowledge

Recently discovered information - not described in the CHEMU Report - allowed this area to be included in this report. Further investigations in the archives are needed to gain more information.

3.2.3.3 Emergency relocation areas

Two relocation areas have been assigned by the Bornholm-located Danish Navy Maritime Surveillance Centre South in the vicinity of the Bornholm dumpsite for the emergency disposal of netted warfare materials too unsafe to be brought and handled ashore. The two areas with a diameter of 0.5 nautical miles and an area of about 270 ha each are located at 55° 4.7’N, 15° 14.2’E and 55° 2.4’N, 14° 37.9’E (WGS84). Of the 112 reported cases of chemical warfare materials caught by fishermen, accounting for altogether about 5,410 kg of warfare agent payload (net weight; *cf.* Figure 15), in the wider area around Bornholm since 1994 (117 cases of which 5 cases were eventually identified as rocks or other material), 22 have been treated ashore. In the remaining 80% of cases (about 4,140 kg of warfare agent payload; net weight), the material has been relocated to the designated areas. In total, 93 cases were related to sulfur mustard warfare materials, including more than 80 lumps of solidified sulfur mustard (*cf.* Annex 7.2 - Table 7).

3.2.4 Gdańsk Deep

Profile of ‘Gdańsk Deep’

Area according to current sea charts

- Depth: 80-110 m (in the wider area)
- Ground: muddy sediments
- Size: 100 ha (explosives dumping ground currently designated in sea charts)

Amounts dumped (approx.)

- 60 tonnes

Chemical warfare agent types

- Sulfur mustard (two incidents in 1954)

Container-types

- Bombs (two incidents in 1954)

Mixing with other warfare materials

- Suspected area marked as formerly used explosives dumping ground

Warning in sea charts

- Explosives Dumping Ground
- Anchoring and Fishing dangerous

Catches & accidents

- Yes (two incidents in 1954)

A chemical munitions dumpsite is suspected to exist in the southern part of the Gdańsk Deep in the Bay of Gdańsk (Andrulewicz 1996), an area with a depth ranging between 80-110 m. A small circular area with a diameter of 0.62 nautical miles designated as a formerly used explosives dumping ground is marked on navigational charts at position 54° 45’N, 19° 10’E.

The presence of chemical warfare materials alongside conventional munitions was first suspected in 1954, after two incidents had occurred in the wider area. In June, a sulfur mustard bomb had been trawled by fishermen active in the area of the Gdańsk Deep and in September, it was reported that a sulfur mustard bomb had been washed ashore on the Hel Peninsula, west of the formerly used explosives dumping ground marked on sea charts (Szarejko & Namieśnik 2009). In the first half of the 1950s, there were also reports of chemical warfare materials filled with sulfur mustard being washed ashore in areas along the Polish coast, all south-west of Bornholm and along the formerly used transport routes towards the Gotland and Bornholm Basins dumping areas: Dziwnów (June 1952, February 1953), Kołobrzeg (September 1952), and Darłowo (July 1955) (*cf.* Annex 7.2 - Table 8).

Following the 1954 incidents in the Bay of Gdańsk, the Polish press published several articles pointing at witness reports. The confirmed amount of dumped munitions in 1954 amounts to 60 tonnes, of which an unknown amount is probably chemical munitions (Barański 1997, Kasperek 1999). The area has been investigated by the CHEMSEA project (*cf.* Chapter 2.3.2.2.2). Based on magnetometric and acoustic scans, four wrecks and several dozens of munition-like objects were detected. Visual inspection of one of the wrecks identified it as a barge, which could have be scuttled with its load of munitions, while some of the other objects were identified as artillery shells. Pollution of the sediments around those objects is currently under investigation.

Sediments

The Gdańsk Deep is covered with mud and clayey mud; the thickness of the uppermost, unconsolidated layer reaches 1 m. The sedimentation rate in the area is estimated to be 1.8 mm/year, meaning the objects in question could be covered by 11 cm of sediments (Bełdowski & Pempkowiak 2007). Bottom water is usually anoxic, with periodic flushes of North Sea water, oxygenating the area during the medium and major inflows.

New information and findings

In the light of evidence, the Gdańsk Deep is probably a minor dumpsite, with only several tonnes of chemical munitions dumped alongside conventional munitions.

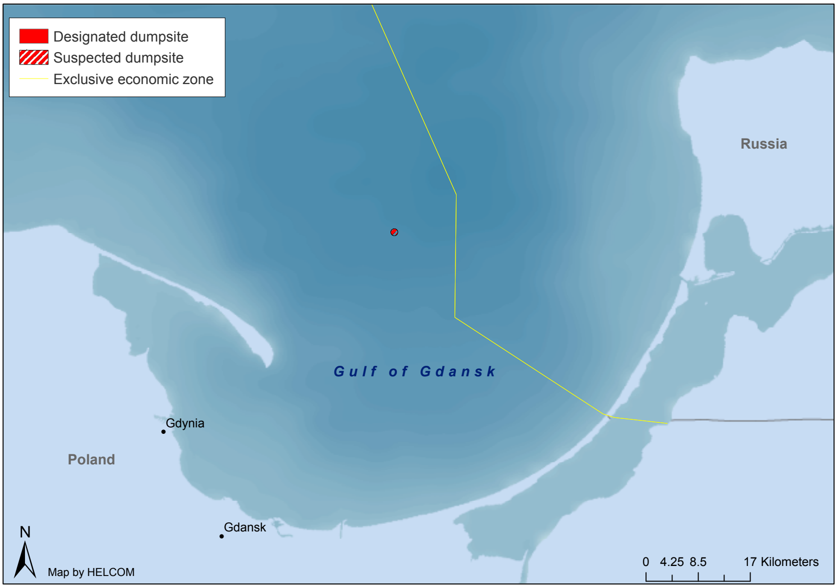


Figure 26: Map of the Gulf of Gdańsk, indicating where the former Explosives Dumping Ground is designated on sea charts. The position and extent of the possible chemical munitions dumpsite is unknown, but it is currently being investigated by the CHEMSEA project.

The extent of sediment pollution is currently unknown. Anoxic conditions prevailing in the area limit the contact of any such pollution with marine biota, although it may still pose a risk for fisherman performing bottom trawling and industrial activity on the bottom. The area was not mentioned in the 1994 CHEMU report.

Since 1997, Poland has conducted several investigations in order to gather new information on dumping operations within the Polish EEZ in the 1950s. The following briefly presents the results of archive studies and assessments in the area.

3.2.5 Beaches of concern for white phosphorus contamination

Nuggets of white phosphorus can be mistaken for amber and ignite upon drying, burning at about 1,300°C. Cases of people suffering from burn injuries after having accidentally come into contact with white phosphorus occur every year.

Figure 27: Self-ignition of white phosphorus nuggets (Picture source: Kevin A. Boudreaux, Angelo State University, USA).

The beaches on the German island of Usedom are an area of special concern for the occurrence of white phosphorus originating from incendiary bombs used during bombing runs on the former testing facility at Peenemünde in 1943. The contamination is estimated to amount to 1.2-2.5 tonnes of white phosphorus. There have been some two to four incidents each year, which has generated extensive media coverage; however, no official itemization has been conducted to date. Recently, on 21 April 2012, two tourists suffered severe burns after collecting amber on Usedom’s beaches. Sporadic encounters have also been recorded in other places along the Baltic coast of Germany (Böttcher et al. 2011).

Another area of concern is Liepāja beach. The contamination at this site supposedly amounts to up to three tonnes of white phosphorus and allegedly exists due to the organized explosive demolition of incendiary bombs in the 1980s. There are annual cases of people suffering burns while collecting amber on the beach.

A case was also recorded in Lithuania in 1992 near the border with Latvia - a piece of white phosphorus was found by local people. Each year, the German and Danish authorities record approximately five cases where location-markers containing phosphorus in small quantities have been washed ashore. No incidents of people being burnt have been reported along the Danish coasts.

New information and findings
Information on the chemical white phosphorous was added to this report - even though it is not a chemical warfare agent - because of the number of reported incidents of people coming into contact with this compound of incendiary munitions, and the importance of disseminating information about its risks and the legacy of warfare materials dumped in the Baltic Sea.

3.3 Types, properties and environmental fate of chemical warfare materials

This chapter focuses on the types of chemical warfare agents currently known or suspected to have been dumped in the Baltic Sea. Warfare agents not known to have been dumped in this area, but likely to have been transferred to the arsenals of the former Allies are not included in this report (e.g., the most advanced agents such as Sarin and Soman).

3.3.1 Introduction

Over time, the metal casings of munitions as well as bulk containers rust and are subject to mechanical erosion. At some point, the hull will be breached and contact between seawater and the chemical contents of a munitions object will be established. When discussing the problem of sea-dumped chemical munitions, corrosion, leaching and the behaviour of the chemicals as such, need to be taken into account.

At the time of dumping, bulk containers may only have contained chemical warfare agent mixtures (including the respective parent compounds, production and storage side products, stabilizers and solvents). Other munitions, however, will have contained explosives used as burst charges and it must be taken into consideration that not all fuzes were removed before dumping (Bruchmann 1953, Jäckel 1969). As in the case of dumped conventional munitions, chemical munitions should be considered as potentially explosive.

Polish investigations on sulfur mustard lumps and German investigations on Tabun grenades have shown that both chemical warfare agent mixtures and explosives are chemicals that may have reacted with other materials in the container or undergone transformations (*cf.* Annex 7.1). Effectively, this aging process inside the encasement may have changed the chemical and physical properties of the contents, making their behaviour in the marine environment more complex (Mazurek et.al. 2001). With regard to chemical warfare agents, compounds with less pronounced or without warfare capabilities may have emerged. Explosives, on the other hand, may have lost their handling safety and might have become sensitive to shocks and thus more dangerous (Pfeiffer 2012).

When seawater comes into contact with these chemicals, it may act as a solvent or suspension agent. Consequently, the chemicals will leak into the environment spreading locally at first and possibly entering a sediment sorption / desorption equilibrium process. Over time, they will be distributed over a larger scale by hydrodynamical processes and anthropogenic activities (*cf.* Chapter 4.2).

Once under the influence of environmental factors, chemicals may also undergo changes caused by abiotic (e.g., reactions with seawater and its components such as dissolved oxygen or hydrogen sulfide; or closer to the surface by sunlight-mediated degradation) or biotic (e.g., bacteria-mediated biotransformation) processes.

The propensity to undergo chemical transformations and the pathways and modes of environmental distribution - taken together as the *environmental* fate of a chemical - is dependent on the nature of the chemical (e.g., reactivity, polarity) and on the prevailing ambient conditions (e.g., temperature, reaction partners, redox equilibrium, sediment properties and bacterial population). The chemicals resulting from these transformations may or may not have properties similar to the parent compounds.

Some parent or transformation chemicals will undergo fast reactions while in other cases transformations will occur only very slowly. The latter chemicals are persistent in the environment and, given suitable hydrophobic (fat-soluble) properties, have the potential to bioaccumulate and biomagnify in living organisms via food webs. As persistent organic pollutants (POPs), they can be considered as significant environmental pollutants.

With regard to organic chemicals, the highest possible stage of chemical breakdown is mineralization (conversion to carbon dioxide, ammonia, water and hydrogen sulfide, for instance). In the case of organometallic (e.g., organoarsenic-based chemical warfare agents, *cf.* Annex 7.1) or inorganic (e.g., metals from containers or the primary explosive lead(II)azide from detonators) chemical warfare materials, transformations will lead to inorganic species of heavy metals, which can be converted to different organometallic species by biotic processes (Maher & Butler 1988). These latter inorganic and organometallic species occur naturally and their toxic properties depend on the chemical 'wrapping', oxidation state and nature of the metal atom, and may either be pronounced or even negligible (e.g., arsenobetaine) (Leermakers et al. 2006, Sharma & Sohn 2009). Nonetheless, since the amount of bioavailable heavy metals introduced by anthropogenic activities is considerable in comparison to the naturally bioavailable amounts, the discharge of heavy metals into the environment is one of the principal issues of environmental pollution.

3.3.2 Chemical munitions and other storage containers

The military sorted chemical weapons into the classes based on 'use' or 'harm'. In the German system, for example, these classes were colour-coded and appeared as painted crosses (WWI) or rings (WWII) on the German chemical weapons (*cf.* Figure 29).

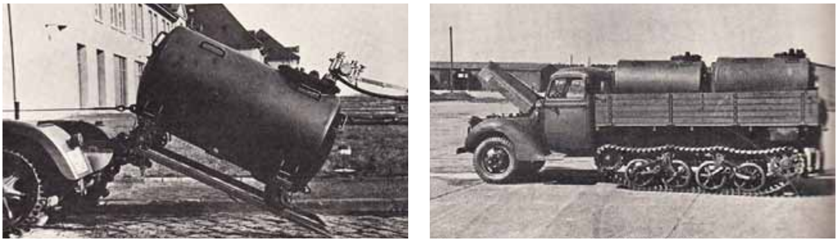


Figure 28: Chemical warfare agent bulk storage and transport container with a capacity of 900 L. When equipped with a special pump-system, it was possible to release the contents during transport on trucks (Rielau 1965).

Chemical warfare agent mixtures have been dumped in diverse types of munitions (*cf.* Table 5), as well as in bulk storage containers such as barrels and drums (Figure 28). These containers have different susceptibility to corrosion and therefore speed of decay and start of content release due to differing wall thickness (e.g., thin-walled aircraft bombs and thick-walled artillery shells), type and the quality of metal(s) used (e.g., the use of a combination of different metals results in contact corrosion) and other contained substances.

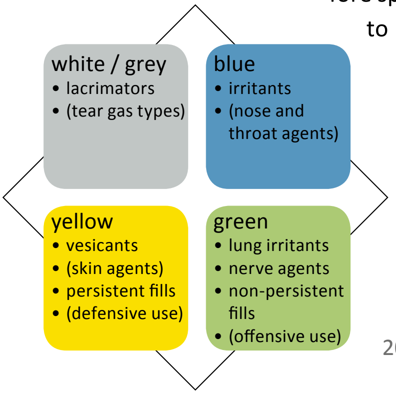


Figure 29: German system of colour codes for the classification of German chemical weapons (U.S. Army 1994, Böttcher et al. 2011).

In contrast to bulk storage containers, munitions contain different types of explosives. Unlike in conventional munitions, the payload of chemical munitions is a chemical warfare agent mixture, not an explosive or incendiary mixture. However, in order for ammunition to have the intended effect, the payload must be released from its metallic container when a certain event happens (e.g., countdown of a set time, shock of impact), for which chemicals with the ability to detonate (explosives) are used. The release event is usually determined by the type of fuze employed in the ammunition. Fuzes usually contain shock-sensitive primary explosives (e.g., mercury(II) fulminate, lead(II) azide), which are used to set off a more stable and handling-safe secondary explosive (e.g., 2,4,6-Trinitrotoluene = TNT), sometimes via additional booster charges (e.g., containing the sensitive explosive picric acid or its salts). These chain reactions burst the container and release the chemical warfare agent payload.

Spreading a chemical warfare agent from its container into the environment needs intentional external force, which is why pyrotechnic or explosive devices are part of many chemical warfare materials. The charges are recognized to be insufficient to distribute chemical warfare agents from a place of origin below 20-30 meters depth to the surface. However, as conventional munitions contain significantly higher amounts of explosives, in cases of mixed dumping (large conventional and chemical munitions), a conventional explosion might generate enough force to spread CWAs for unforeseen distances.

Table 5: Common types of German WWII chemical munitions, compiled from (Koch 2009, Wichert 2012). The weight of the chemical warfare agent payload is given, but depends on the type of chemical warfare agent mixture contained (*cf.* Annex 7.1): blue and white ring munitions (α-chloroacetophenone, Adamsite, Clark-types) typically with a lower weight; yellow and green ring (sulfur mustard, nitrogen mustard, Tabun, phosgene) with the highest weight.

Type of encasement	Gross weight	Chemical warfare agent payload		
		Net weight	Net weight ratio	Type(s)
75 mm Infantry shell	5 kg	1.4 kg	28%	α-chloroacetophenone
105 mm Field Howitzer shell	13-15 kg	0.5-1.8 kg	< 14%	Adamsite / Clark-types, arsine oil / sulfur mustard / Tabun / and tactical mixtures of the agents
150 mm Field Howitzer shell	37-42 kg	1.5-4.8 kg	< 13%	same as 105 mm shells / nitrogen mustard
100 mm Mortar grenade	7 kg	1.5 kg	21%	sulfur mustard in tactical mixtures with Clark-types
150 mm Launcher rocket	35 kg	3.1-4.6 kg	13%	sulfur mustard / Tabun / nitrogen mustard
Spray Can 37	> 12 kg	10 L	High	(thickened) sulfur mustard
KC50 Aircraft bomb	43 kg	13-15 kg	30-35%	Adamsite
KC250 Aircraft bomb	140-146 kg	86-110 kg	60-75%	(thickened) sulfur mustard, also in tactical mixtures with Clark-types / α-chloroacetophenone / Tabun / phosgene

The speed of corrosion and subsequent release of the chemical contents strongly depends on the local environment in which the container of chemical warfare material rests. In general, the presence of oxygen, high salinity and engulfing currents will accelerate corrosion, while burial in sediment and a low oxygen environment will preserve its original state for a prolonged time.

Figure 30: Corroded chemical munitions recovered from the Baltic Sea in recent decades. Left to right: 15 cm Tabun shell, 1960; KC250 Tabun bomb, 1960 (Picture source: Internal Documentation State Office for Civil Protection – bomb disposal services); empty KC250 bomb (Picture source: Maritime Surveillance Centre South on Bornholm).

The oxygenation of the deep basins of the Baltic Sea is particularly dependent on the periodical inflows of water from the North Sea (*cf.* Chapter 4.2.1.3). The absence of these inflows for prolonged periods contributes to an oxygen-deficient environment. However, even under these oxygen depleted conditions, corrosion can occur under the influence of hydrogen sulfide-forming (sulfate-reducing) and iron-oxidizing anaerobic bacteria (Videla & Herrera 2005).

From the experience of the Danish Navy Maritime Surveillance Centre South on Bornholm, the hulls of chemical munitions are more likely to have been breached than the thicker hulls of conventional munitions. Sanderson & Fauser collected information pertaining to the Bornholm area and found that the munitions accidentally trawled by fishermen had been heavily corroded and that sulfur mustard lumps had become hard and solid. Conversely, local divers reported that munitions buried in sediment were largely intact (Sanderson & Fauser 2008).

However, as the processes and factors influencing corrosion are complex, it is difficult to make general statements on the current state of the corrosion of sea-dumped munitions in the Baltic Sea. Even objects of the same type and age found within a nautical mile of each other may show differences (Figure 31). It needs to be stressed that even if the outer hull is still intact, the chemical contents of bulk containers or munitions casings may have changed over time (the latter being more likely due to their more complex composition).

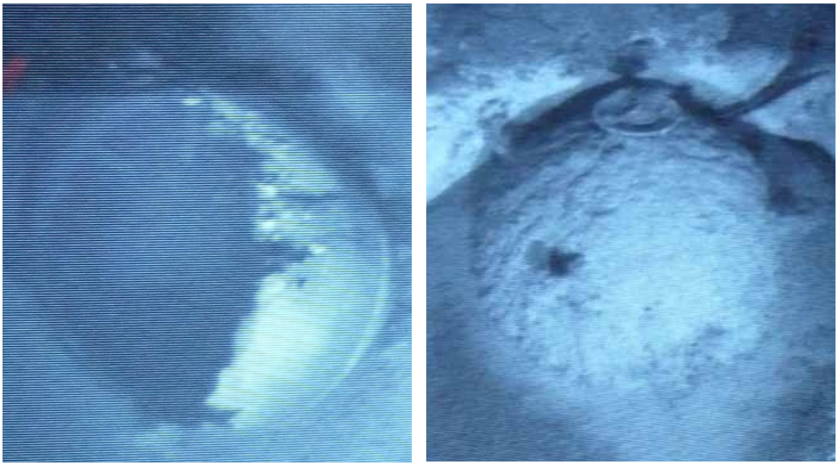


Figure 31: Two sea mines, originally laid on the same day and found in the middle of the Baltic Sea within a distance of approximately 1400 meter of eachother, exemplify the differences in state of corrosion of encountered munitions (Wichert 2012).

Chemical warfare agents discussed in this report can be classified into groups according to their main effects on humans upon direct contact and airborne exposure (*cf.* Figure 32). For more information about the chemical warfare agents, see Annex 7.1.

Chemical warfare agents

Vesicants (blister agents): sulfur mustard, nitrogen mustard, Lewisite

Irritants (nose and throat agents): Clark I, Clark II, Adamsite

Lacrimators (tear gases): α-chloroacetophenone

Lung agents: phosgene, diphosgene

Nerve agents: Tabun

Blood agents: hydrogen cyanide

Figure 32: Effect-based classification of chemical warfare agents (HELCOM 1994).

4 Potential threats to the marine environment and humans

This report does not include an ecological risk assessment but presents the most up-to-date information available as well as potential model-based approaches on possible biological effects of chemical warfare materials.

Technical risk assessment and risk management

Risk management decisions are in most cases based on risk assessments, and in rare cases based simply on hazard assessments by invoking e.g. the precautionary principle (if the intrinsic hazard is so great that the probability of an incidence does not change the decision making anyway, or if the scientific uncertainty is so great that it is unfeasible to attempt to reduce this). Precautionary decision making may also be warranted if the decisions lead to non-regret measures, or if the no one is in any ways harmed by the decision – e.g. cost neutral. In almost all other cases a risk based approach is preferred. Risk based decision making supports a transparent, science based, and cost-effective environmental regulation (hence the EU has produced a technical guidance document for chemical risk assessment (EU TGD, 2003: http://ihcp.jrc.ec.europa.eu/our_activities/public-health/risk_assessment_of_Biocides/doc/tgd) which should be the starting point of any chemical risk assessment in the EU). There is no doubt that sea-dumped chemical warfare materials are inherently hazardous - as this is the purpose of the compounds - the risk, however, is low if the exposure is either highly unlikely or very low. Environmental risk is characterized by the PEC/PNEC quotient, where PEC = the Predicted Environmental Concentration and PNEC is the Predicted No-observed Effect Concentration. Hence, if the PEC is very low e.g. 0.0001ppb and the PNEC is 0.01ppb then the risk quotient is 0.0001/0.01ppb = 0.01 = low risk - despite a high toxicity – in other words: high toxicity * low exposure or low probability of exposure = low risk.

In complex site-specific risk assessments it is often necessary to use a weight-of-evidence approach, as simple risk calculations may not provide the full picture. In these cases, several lines-of-evidence are collected, not only measurements, but also more qualitative data from e.g. local experts such as fishermen. The sum of the lines-of-evidence will determine the weight-of-evidence and the acceptance or rejection of the hypothesis being tested.

Coming into contact with chemical warfare materials is dangerous for many forms of life, most notably humans, other mammals, birds and fishes. The knowledge on the interactivity of chemical warfare agents with microorganisms is still fragmentary. With regard to humans, in general, the likelihood of an incident increases when individuals are occupationally active in areas contaminated with hazardous materials. In order to manage the risk and cope with the present danger, risk management techniques could be employed to help prevent injuries and fatalities. Due to the many factors involved, it is challenging to assess the all the relevant risks at a specific site or in a planned operation, for example.

The current methodology for coping with foreseeable hazardous situations is based on a general model, which describes the degree of a hazard in relation to the degree of danger and the likelihood of a plausible incident. The Standard 31000 (issued in 2009) and related documents of the International Standardization Organization (http://www.iso.org) and EU guidelines (applicable to EU Members States only) describe the general procedure and define the terms. The resulting assessment will indicate priorities within a mitigation strategy.

4.1 Introduction

Hazard

A hazard describes a situation posing a level of threat to a valuable asset.

Examples for hazard-influencing factors

- type of chemical warfare agent mixture - e.g., nerve agent, contact or blood poison
- level and type of toxic activity - with respect to aging and formation of degradation products (e.g., Tabun may have decomposed to hydrogen cyanide)
- type and additional hazards posed by a container - in contrast to bulk storage containers, munitions may explode
- integrity and functionality of a container - state of corrosion of encasement, condition of fuze, detonator and ejection charge
- magnitude of explosive hazard and amount of contained explosives - depending on the object
- physical condition and behavior of chemical warfare agent mixtures - with respect to aging and prevailing environmental conditions, respectively (influenced by, e.g., water pressure, pH-value, redox conditions, salinity and currents)
- changes in physical condition and behavior of chemical warfare agent mixtures due to disturbance – also with respect to the integrity of aged encasements or solidified chemical warfare agent lumps (e.g., upon resurfacing due to changes in external pressure and oxygen availability)

Figure 33: Potential factors pertaining to the type and condition of chemical warfare materials to be considered for hazard assessments.

Most of the present hazards are not acute, but dormant or potential. There might be no risk of being harmed by a toxic substance, for example, because enough distance separates the threat-posing object from the valuable asset and so exposure is effectively eliminated.

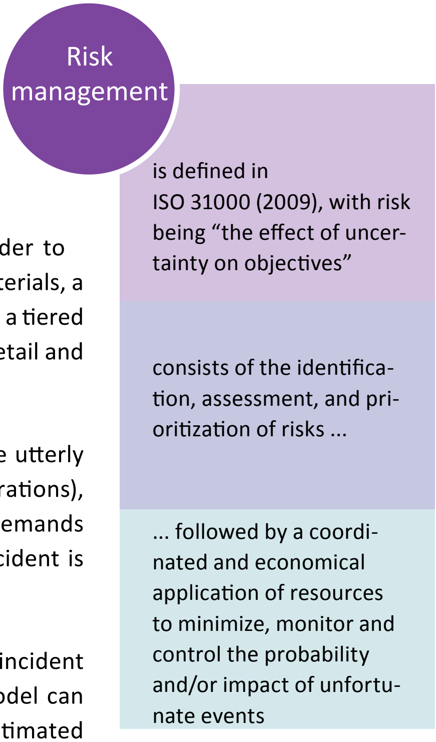
Risks posed by chemical warfare materials vary and are influenced by a large number of factors. Recognizing the relation mentioned above, it is necessary to assess specific situations carefully and in advance. If hazards are present, it is necessary to estimate the likelihood of different types of possible contacts and the potential seriousness of the consequences.

Risk assessment

A simplification of risk assessment consists of a probability multiplied by an impact (Hubbard 2009). According to this, the risk can be 'zero' if there is either no chance of an impact or the occurrence is impossible. In order to assess the risk concerning chemical warfare materials, a range of possible impacts must be ascertained in a tiered approach, depending on the required level of detail and understanding of exposure.

Unless the occurrence of an incident cannot be utterly excluded (e.g., by discontinuing planned operations), dealing with risks in a responsible manner demands that the likelihood of the realization of the incident is assessed.

By indicating the potential seriousness of an incident (e.g., injury), a responsible risk assessment model can both evaluate the more likely events with estimated temporary health impacts and the most unlikely incidents with potentially fatal consequences.


Risk management

is defined in ISO 31000 (2009), with risk being "the effect of uncertainty on objectives"

consists of the identification, assessment, and prioritization of risks ...

... followed by a coordinated and economical application of resources to minimize, monitor and control the probability and/or impact of unfortunate events

Figure 34: A short definition of risk management.

In order to assess the risk in a certain situation, the general factor of vulnerability has to be taken into account in relation to the present hazard. A vulnerability index, based on the factors of likelihood and seriousness of an incident, can integrate and represent the behaviour of humans, environmental influences to hazards and the quality of damage after a hazardous situation has turned into an incident.

Figure 35: The components of risk.

Risk management

If valuables are under threat of being exposed to a hazard, the guarantor will consider mitigating strategies that could be implemented. When preparations to cope with the assessed hazard are made, the likelihood and seriousness of an incident may decrease. In theory, the introduction of the index capacity may lower the 'vulnerability' level. Conversely, a high 'vulnerability' in a certain situation indicates the need for strong capacity.

According to present recommendations concerning risk management and dumped chemical warfare materials, the investigation of risks should focus on the objects expected to be found and the motivation to protect. The factors shown in Figure 36 cannot be described independently from each other. In order to assess a situation in a responsible manner, however, all different contributing factors need to be investigated, and in most cases, a web of dependencies will occur, not just a risk chain. More examples and dependencies that can be recognized as a general framework are listed in Annex 7.4.

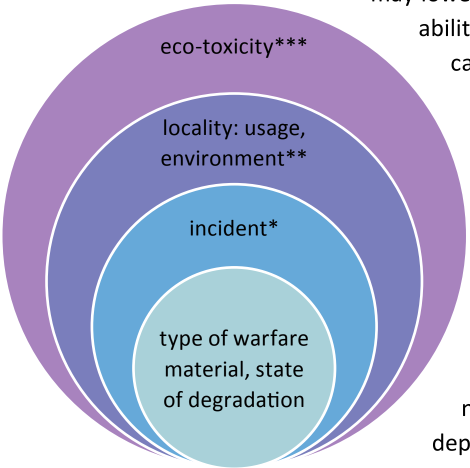


Figure 36: General factors to be considered for responsible assessments.

Risk in relation to chemical munitions

Whether the risk of chemical warfare materials is decreasing or increasing depends on the situation. For instance, the total loss of containment due to the corrosive disintegration of a container may be a risk-decreasing factor with regard to its potential recovery by fishing – unless the warfare agent mixture has solidified, forming a casing by itself. However, with regard to the marine environment, the release of contaminants into the environment may be assessed as a risk-increasing factor.

The various chemical warfare agents were invented for a number of different military tactical options. Consequently, they interfere with humans in different ways and with different effects upon or after contact. The acute toxic effects range from the short-term incapacitating effects of tear gas, via the mid-term incapacitating skin-damaging effects of sulfur mustard to the fatally nervous system-interfering effects of Tabun. Beyond this, chemical weapons such as bombs, artillery shells and spray cans ('Sprühbüchse 39') also contain explosives or pyrotechnical constituents that help 'shower' the chemical warfare agent payload over the designated area.

In addition to acute toxic effects envisaged from the military application of the substances, exposure to chemical warfare agents may cause delayed defects in the long run, after single contact or long-term, low-level exposure. These can take the form of psychopathological-neurological changes; malignant tumours (cancer); increased susceptibility to infectious diseases (primarily of the lungs and upper respiratory tract); disturbances in the liver's function; pathological changes in the blood and bone marrow; eye lesions; premature decline in vigour; and rapid aging and related functional disturbances such as decline in potency and libido. In addition, most notably for sulfur and nitrogen mustard, mutagenic, teratogenic and embryotoxic effects can occur (SIPRI 1975).

In summary, the statement made in a 1975 SIPRI study on the delayed toxic effect of chemical warfare agents applies (SIPRI 1975): "The hazards of chemical warfare agents are by no means adequately described simply by their acute effects."

4.2 The relocation and spreading of warfare agents

As described in Chapter 3, most dumping activities in the Baltic Sea have been carried out by the item-by-item disposal of chemical warfare materials, sometimes even en route to the designated dumping areas. Consequently, warfare materials have been scattered in high density within or in the vicinity of the designated dumping areas - and in low density also outside of them. In addition, natural processes like currents and human activities, such as fishing with bottom trawls, contribute to the on-going re-distribution of both chemical warfare materials objects and contaminated sediments in the marine environment.

Chemical warfare material objects are point sources of contamination. It is certain that with time, these objects will be broken down due to mechanical and chemical processes to become diffuse sources of local contamination, which will then be further distributed. Spreading may occur in solution or as particles bound to sediment particles or in biota (Figure 37), and may be accompanied by abiotic or bio-mediated chemical transformations of the released compounds. Thus, the disintegration of containers results in additional uncertainty with regard to the environmental fate of the formerly contained pollution

Figure 37: Small lumps of sulfur mustard in the fish conveyor belt on board a fishing vessel. Since it could not be ruled out that some of the particles actually might be explosives, they had to be emergency-relocated (*cf.* Chapters 3.2.3.3 & 4.3.1) (Picture source: Maritime Surveillance Centre South on Bornholm).

load, taking into account that this is determined by the type of released compounds and the prevailing ambient conditions. As a result of further dissolving, dilution and the reaction of decomposition (dissipation), the possibility of the occurrence of high concentrations of chemical warfare agents in the seawater seems unlikely.

Anthropogenic-driven relocation and spreading due to natural processes differ in magnitude and type of force. In general, activities capable of moving large objects like bombs or lumps of sulfur mustard will also be sufficient to achieve the spreading of contaminants in solution, as particles or bound to sediment particles. However, some activities affect larger objects more than particles and vice versa. For instance, when bottom trawls are drawn over an area of contaminated seafloor, contaminated sediments may be re-suspended and the contamination may only spread locally; however, chemical munitions caught in a net may travel a long distance before being released.

4.2.1 Natural processes

Natural processes potentially causing the relocation and spreading of munitions and chemical warfare agents can be separated into those occurring on a permanent basis, frequently or only occasionally:

- *Permanent* – low force – diffusion from sources (e.g., resulting in the contamination of adjacent sediments, pore water and water in the immediate vicinity of the leaking chemical munitions).
- *Frequently* – low to medium force – horizontal currents of ordinary magnitude; disturbance by biota (bio-turbation); and vertical transportation with biodegradatively generated gas in the sediment and pore water from deeper layers, squeezed out due to the increasing weight of settling particles.
- *Occasionally* – stronger force – extraordinary events like the inflow of cold, salty and oxygenated water from the North Sea into deep basins of the Baltic Sea; strong currents caused by storm surges and ice (in more shallow or coastal waters).

The potential impact of these processes also depends on many local factors such as water depth; the depth of buried objects or point sources in the sediment; the composition of the upper layer of the seabed; and the temperature of the water.

4.2.1.1 Permanent effects

Chemical warfare materials may be completely or partially buried in the sediment or they can be lying on the surface of the seafloor. Once the integrity of an encasement is breached, the contents of any object will spread due to the processes of advection and diffusion within the sediments and the water in the immediate vicinity of the point source. As described in Chapter 3.3, some chemical warfare agent-associated compounds, when released into the environment, undergo a quick chemical transformation and detoxification; while other compounds might persist in the environment for long periods due to various factors (e.g., stability towards hydrolysis by the formation of self-contained lumps).

While advection is related to the movement of ambient media in duration and velocity, molecular diffusion follows any relative difference of concentration, which is a very slow process. It needs to be noted, however, that muddy sediments dominate the former dumping areas in the Baltic Sea and their permeability is so small that the process of dispersion caused by advection currents – either induced by density or resulting from the pressure gradient – can be disregarded.

4.2.1.2 Frequent hydrodynamic effects and bio-turbation

The water of the Baltic Sea is circulated, most notably forced by wind, but also by differences in water temperature and/or salinity and oxygenation levels which drive the movement of water. Strong forces may only occur in shallow waters and near to the shore. For instance, the maximum speed of currents in the Bornholm Basin has been measured at 20 cm/s at five meters above the seabed and up to 40 cm/s at forty meters over the seafloor (Garnaga & Stankevičius 2005, Missiaen et al. 2010). In addition to horizontal movements, the water also undergoes vertical mixing.

Findings made after the CHEMU Report (Paka & Spiridonov 2002) show that other noteworthy near-bottom turbulences occur in deeper waters as well. Two effects that might lead to the expulsion of contaminants from the seabed into the water column, and which could then be relocated by horizontal currents, have been described:

- Settling sediments - the increasing weight of the growing and settling of the topmost sediment layer results in the expulsion of water from deeper sediment layers that might carry (micro)particles/contaminants.
- Rising gas - generated by anaerobe biological degradation fermentation gases can form small bubbles rising upwards and causing microturbulences on the way, resulting in particles/contaminants being dragged along and ejected from the seabed.

Diverse species of biota inhabit the seabed or visit it regularly to feed on benthic organisms. When animals dig burrows into the seafloor or scour the sediment for prey, the layers of particles are mixed and released into the near-bottom water. Contaminated sediments will also most likely respond to these disturbances of the seafloor or accompanying near-bottom water movements. If the exposure to toxic chemicals is minor, the benthic organisms will not suffer from acute toxic effects; upon prolonged exposure, however, chronic effects are possible.

4.2.1.3 Occasional and extraordinary effects

Occasionally, oxygenated and salty water flows from the North Sea into the Baltic Sea. Due to its higher density, this water will replace the oxygen-deficient and less salty water of the deep basins from the deeper slopes towards the ridges. This salt water influx is recognized to have an important biological effect on the Baltic Sea's ecosystem. It used to occur on average every four to five years until the 1980s, but in recent decades it has become less frequent. The latest three inflows occurred in 1983, 1993 and 2003, suggesting a new inter-inflow period of about ten years.

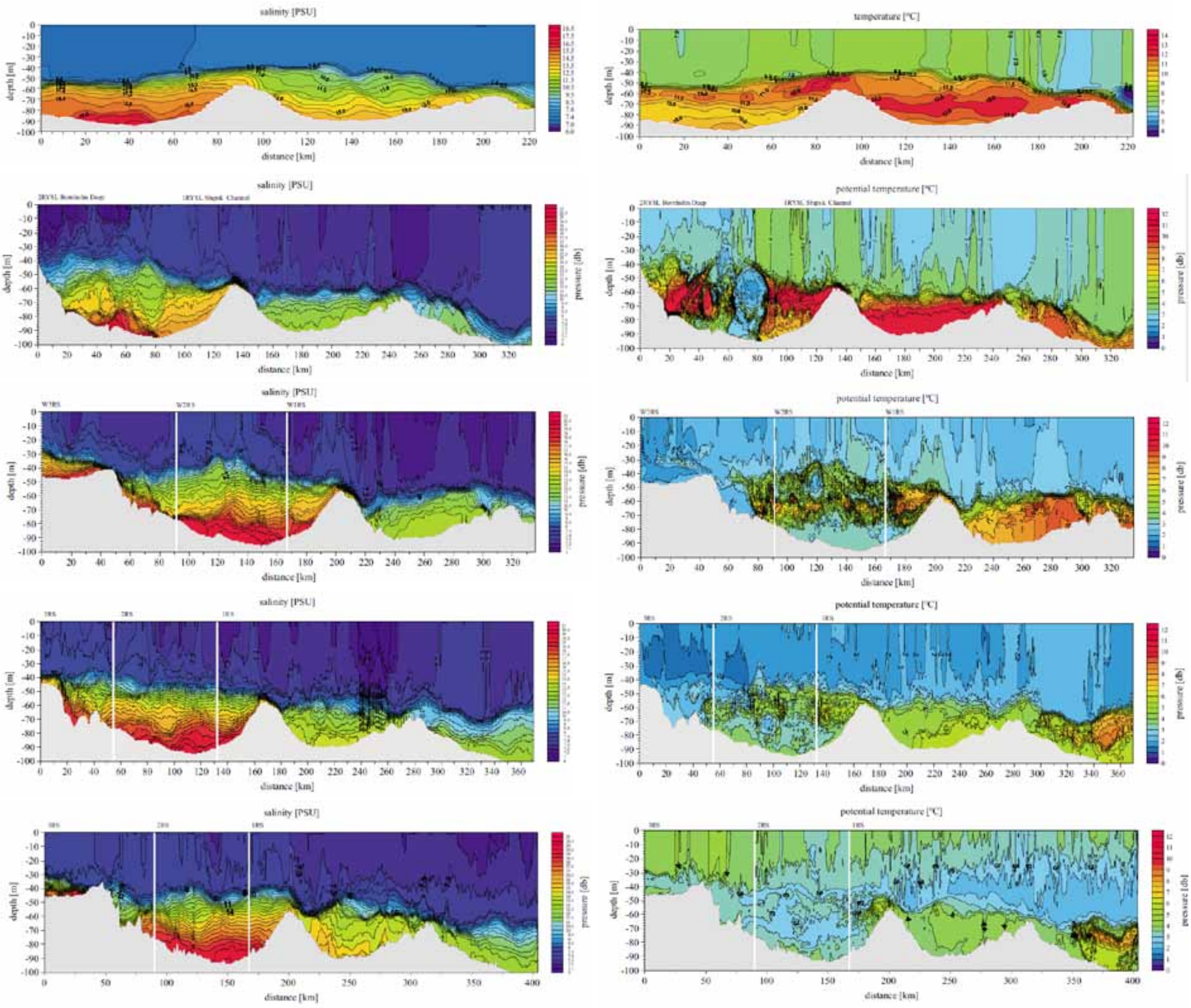


Figure 38: Bornholm Deep – Słupsk Channel – Gdańsk Deep transects measured by RV 'Oceania' in December 2002-April 2003 (from top to bottom), showing the eastward propagation of warm inflow water over the Słupsk Sill into the south-eastern Gotland Basin (Piechura & Beszczyńska-Moeller 2003).

The phenomenon of the North Sea water inflow into the Baltic Sea is accompanied by near-bottom turbulences. The magnitude of the physical force applied to contaminated particles in the deep basins, also formerly used as dumping grounds for chemical warfare materials, was investigated in a joint Polish-German study (Feistel et al. 2004, Piechura & Beszczyńska-Moeller 2003) which found that within two months, the entire amount of warm and poorly oxygenated water was fully replaced by cold water of higher density and oxygenation (Figure 38). An energetic motion close to the sea bottom was also observed, which interacts with the sediment and with any objects inside and on it.

Furthermore, strong wind-driven currents and storm surges also need to be studied as they occasionally cause extreme movements in the water body. Even if storm surges or ground swells themselves might not affect deeper layers of the water body, the effect of ‘sloshing’, a characteristic of the Baltic Sea, will occasionally lead to strong currents that compensate for the loss of water on the wind-facing side of the Baltic Sea by water movement. Large volumes of water are forced by the wind and lead to turbulences that might drive water through the horizontally layered system and cause an extraordinary vertical exchange of the water as well as the biota and non-biota contained within. Theoretically, the occurring forces might even be sufficient to carry objects to the shore - at least those objects floating in the water column or resting in the vicinity of the shoreline. In the cases that have been documented where munitions dumped in wooden crates or with basket-style protection casings were found on the beaches of the Baltic Sea (*cf.* Chapter 3), all appear to be related to the years when the dumping activities were conducted or in the ensuing decade. However, even entire munitions objects like artillery shells have been observed to be relocated in coastal and shallow waters naturally, i.e. caused by large amounts of ice during cold winters.

The directions of movement of the suspension in near-bottom water at the Bornholm dumpsite were investigated during the MERCW project using a modelling approach (*cf.* Chapter 2.3.2.2.1). The model is currently the only one existing for the transportation of suspensions and suspended particles in the areas contaminated with chemical warfare material in the Baltic Sea (Zhurbas et al. 2010). According to the model’s calculations, the suspension in the area of the Bornholm dumpsite reaches the near-bottom currents surrounding the deep in the north and the south when easterly and northerly winds prevail. When the particles reach these currents, they can be transported away from the dumpsite. With westerly and southerly winds, the particles in the suspension are contained in a cyclonal whirl in the centre of the deep if their speed of falling exceeds 1.3 m (for southerly winds) and 1.6 m (for westerly winds per day).

The effects discussed above lead to the conclusion that the likelihood of contamination spreading increases inversely according to the size of the object: the smaller the contaminant becomes, the wider it will be spread out. Due to the some of these hazardous substances having toxic effect even at very small doses, the risk will most likely increase with the continuing (corrosive) disintegration of the encasements and larger particles by physical and aging processes.

4.2.1.4 Surf-zone effects

To date, the limits of an object's size, form and weight up to which relocation by currents and waves is possible are not known. Recurring reports about artillery shells, parts of torpedoes or the engines of WWII cruise missiles (V1) found in the surf zone of beaches suggest that there is a natural process of transportation, but one which is not completely understood as yet. It is well understood that the force of waves rolling towards the shoreline increases with decreasing water depth. As a result, it can be concluded that objects will be relocated by waves either due to their low density in relation to seawater and / or if they are located in shallow water.

Munitions constituents can also be washed ashore. Incidents are recorded nearly every year of small pieces of the incendiary agent white phosphorus being found in the surf zones of the German island of Usedom and the Latvian beach south of Liepāja. Reports from other locations are rare. In the cases of Usedom and Liepāja, the toxic substance originates from the payload of incendiary bombs that were released into the sea close to shallow water (*cf.* Chapter 3.2.5). As the encasements of incendiary munitions are rather thin, it is likely that some would have ruptured on impact; for those that did not, by today they are probably in an advanced state of corrosion and may even have broken up into pieces. In some munitions, solid white phosphorus was used while in others the incendiary substance was mixed with rubber-like sticky additives. The original substance which broke up into pieces upon impact or by waves has by now, most likely, been relocated naturally.

4.2.2 Anthropogenic activities

Taking into consideration the surf zone effect, the common conclusion is that the horizontal relocation of large and heavy warfare materials is caused by anthropogenic activities. The force required to move containers or heavy munitions (e.g., large artillery shells or chemical bombs weighing up to 200 kg) over noteworthy distances cannot be applied by natural processes. Only trawled fishing nets, dredgers or other large machinery moving along the seabed (e.g., for laying pipes or power lines) are recognized as being able to relocate large objects over significant distances along the Baltic deep basin seafloor. The relocation of warfare materials may occur unintentionally, most likely involving objects resting outside the dumpsites marked on navigational charts and possibly without the crew even being aware of it.

In this context, the former practice of en route dumping is of special interest since these chemical warfare materials pose a considerable risk - one that is very difficult to assess due to the unknown locations outside the assigned dumping areas and because they were disposed of and scattered item-by-item. While the likelihood of trawling one of these objects is low, any such incident might have severe consequences due to the unexpected event and improper preparation.

4.3 Present threats to humans

As discussed in Chapter 3.3, chemical warfare agents like sulfur mustard, Tabun and arsenic-containing substances were designed to trigger severe biological effects at very small doses. All of them are extremely toxic to humans. In many cases, the degradation products also show some degree of toxicity, while some compounds have the potential to be biomagnified.

This section mainly addresses potential exposures for the main users of the sea.

The threats of chemical munitions can be triggered in many ways: the munitions might function as intended and release the toxic contents by detonation after being improperly handled. A more likely scenario is direct or indirect contact (e.g., via vapours) to leaked liquid or solid chemical warfare agents that has become attached to an object (e.g. fish) or contaminated the sediment. In principle, the introduction of chemical warfare agents and their degradation products into the marine food web can result in contaminated seafood products for human consumption and thus pose a risk to seafood consumers, however, only one such case has been documented in the Baltic Sea region (*cf.* chapter 4.3.8). While hazardous chemicals like white phosphorus have been found on beaches, no cases of chemical warfare agents washed ashore have been reported since the HELCOM reporting system was established in 1994.

4.3.1 Fishermen

According to reported incidents, fishermen have been the main group affected by chemical warfare agents since dumping activities were concluded in the immediate post-WWII period (*cf.* Annex 7.2). The risk of coming into contact with the dangerous materials was seen to be highest when fishing inside or near to the former dumping areas. For this reason, these sites are marked on the official sea charts together with additional information on where fishing activities, anchoring and extracting seabed materials is not advisable. However, due to the former practice of en route dumping and the ensuing relocation of sea-dumped materials, there is also a risk when fishing is carried out outside the marked dumpsites.

Figure 39: Lumps of solidified sulfur mustard trawled up with a catch. Since they contain explosives (left - bursting charge tube with about 15 kg of explosives visible), they were emergency-relocated (*cf.* Chapter 3.2.3.3) (Picture source: Maritime Surveillance Centre South on Bornholm).

For the purpose of relocating extremely dangerous chemical warfare materials, two small areas have been closed to traffic around the Danish island of Bornholm (*cf.* Chapter 3.2.3.3). These areas are used on the request of the Danish Navy when chemical warfare materials assessed to potentially contain explosives have been trawled up by fishermen (e.g., remnants of the explosive-filled burst charge is potentially hidden inside a lump of sulfur mustard).

All fishing vessels operating in the areas are required to carry advanced first aid kits in case of contamination and all crew members trained to handle an incident according to approved national contingency plans should it occur. Further general recommendations can be found in Annex 7.3 to this report.

Figure 14 shows the locations of officially reported chemical warfare material catches by fishermen in the waters around Bornholm between 1994 and 2012, which totals some 5.4 tonnes of warfare agent mixtures (net weight, *cf.* Annex 7.2 - Table 7). As discussed in Chapter 4.2.2, the reported location of the catch does not necessarily reflect the resting place of the item before being trawled up. Figure 41 shows the number of reported incidents between 1968 and 2012.

Figure 40: A 45 kg lump of solidified sulfur mustard trawled up with the catch. Since it contained explosives, it was emergency-relocated (Picture source: Maritime Surveillance Centre South on Bornholm).

Although the Danish Ministry of Defense is not liable to pay compensation for any losses suffered by fishermen related to the catch of warfare materials, fishermen from Denmark, Greenland and the Faroe Islands are normally compensated for damaged gear and contaminated discarded catch, in case chemical munitions are trawled up outside the areas marked on sea charts. Between 1968 and 1984, 202 catches amounting to 395 tonnes of seafood had to be destroyed (*cf.* Annex 7.2).

HELCOM maintains an annual record on the reported incidents related to chemical munitions caught by fishermen (*cf.* Annex 7.2 - Table 7). Sulfur mustard-type materials have accounted for 88% of all reported fishing incidents, possibly due to the formation of persistent lumps. Danish statistics are seen to be reliable due to Danish regulations, but the other Baltic states do not have compensation systems in place or obligations to report incidents. Consequently, most incidents have been reported by Denmark - the Swedish Coast Guard have also reported an incident in 2001 and another in 2002.

As seen in Figure 41, there is a clear decrease in the annual number of reported incidents, with the exception of 2003. Possible reasons for this decrease are changes in the local abundance of fish, fewer fishing hours, the use of state-of-the-art fishing gear and gaps in national reports. As there are uncertainties associated with the reporting of incidents, the figures do not necessarily reflect the actual situation. The change in the early 1990s coincides with the decline of the fishing activities in areas off Bornholm.

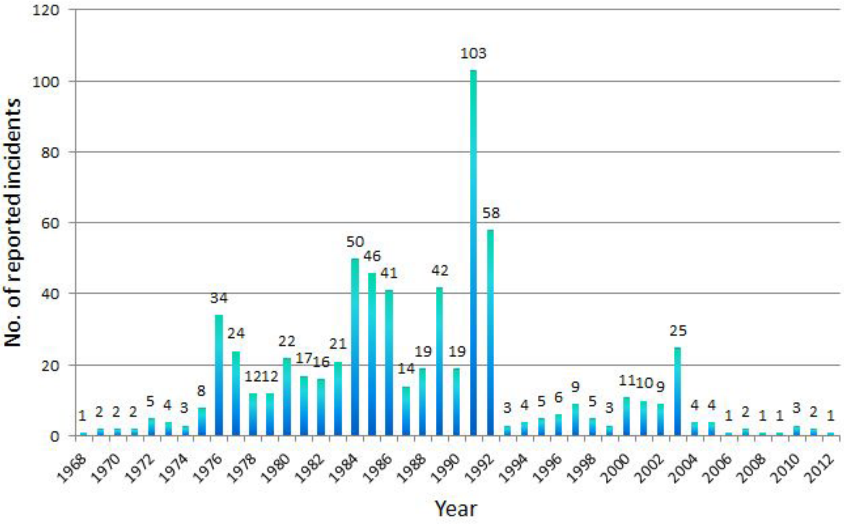


Figure 41: Number of reported incidents of trawled up chemical warfare materials in the years 1968-2012 (*cf.* Annex 7.2 - Table 7-9, SACSA 1991, HELCOM 1994).

4.3.2 Offshore construction and maintenance workers

The rapid growth of the offshore industry is accompanied by changes in human behaviour and thus raises many new issues related to munitions (both conventional and chemical) dumped at sea. The documented experiences of the Nord Stream pipeline laying project between 2005 and 2011 could be a model for future project plans (Nord Stream AG 2010-2011). It substantiated the claim that chemical munitions are a threat to developments in areas outside the limits of 'foul grounds' and munitions dumpsites marked on navigational charts.

The use of the seabed for offshore activities such as resource extraction and construction is rapidly developing and increases the likelihood of encounters with dumped munitions. Offshore construction sites are a good example: where piles are rammed into the seabed there is a possibility to encounter munitions buried deep in the sediment. Available technologies to detect objects in terrestrial soil are insufficient, as are most of the present solutions for underwater detection.

The increased drilling of boreholes for geological surveys also increases the threat of coming into contact with toxic substances, which might occur if a chemical warfare object is punctured in the process or if examined sediment core samples include sediment which has been contaminated with chemical warfare agent mixtures.

The increasing amount of activity on the seafloor also increases the risk of coming into contact with chemical warfare agents. Many temporary or permanent facilities will be deployed on the seafloor in the near future (e.g., Remotely Operated underwater Vehicles (ROV), maintenance stations, offshore wind farms, sea cables and pipelines). Operations on or in the sediment layer may damage the encasements of chemical munitions that have not yet lost their integrity. Moreover, all of these installations are at direct risk from relocated military objects. Apart from the possible direct contact with hazardous objects, the operating personnel are also indirectly at risk from coming into contact with contaminated equipment such as tools, ROVs, diving suites and related gear.

4.3.3 Sub-surface entrepreneurs and workers

Commercial, navy and emergency response sub-surface entrepreneurs and members of service crews related to underwater operations are seen to be exposed to an elevated probability of coming into contact with chemical warfare agents in the vicinity of dumpsites or scattered munitions, be it directly and indirectly, intentionally or unintentionally. Poor underwater visibility, the large variety in shapes of chemical warfare material containers and the degree of their corrosion and colonization by biota pose a challenge to even recognizing the potential danger. It should be stressed that some warfare agents will even penetrate the material of highly sophisticated gloves and diving suits and some substances (e.g., thickened sulfur mustard mixtures), may stick firmly to the surface of objects they come into contact with.

Figure 42: Protective measures taken during investigations into the western part of the Lithuanian EEZ in June 2003, inside the dumpsite area of the Gotland Basin (*cf.* Chapter 2.3.2.1.5) (Picture source: G. Garnaga).

The planning and preparation processes for sub-surface operations in suspected areas should include the implementation of standard operation procedures (SOP) for the unlikely event of an accidental contamination of workers or equipment. All personnel should be considered responsible for correctly carrying out such standard operation procedures. In the event of an encounter, the relevant national authorities must be informed and should thoroughly investigate and formally agree before the operation can be continued.

4.3.4 Harbour staff and workers

Investigations in local archives have confirmed that at almost all harbour facilities used for trafficking of chemical warfare materials, accidents with these hazardous goods have occured (e.g., Flensburg, Wolgast). For the port of Flensburg, two accidents are recorded in relation to the turnover of warfare material in the immediate post-war period in 1945 (18 September, 1 October), as well as single recent incidents have been recorded in Denmark. While unloading rail cars with chemical munitions on behalf of the British Military Administration in Germany, workers were contaminated with sulfur mustard oozing from artillery shells damaged by fire or from barrels leaking due to unknown reason. The contaminated objects were sent off for emergency sea-dumping with immediate priority (*cf.* Chapter 3.2.3.3).

It must also be assumed that the soil is contaminated in parts of the port which were formerly used for trafficking of chemical warfare materials.

Figure 43: A 900 L container of unknown origin (*cf.* Figure 28) with 1,057 kg of Clark I-type chemical warfare agent mixture was found in a warehouse in the port of Nexø in 2001 (*cf.* Annex 7.2 - Table 7). It was decontaminated and the contents disposed of in a disposal facility (Picture source: Maritime Surveillance Centre South on Bornholm).

As described for other sub-surface operations under Chapter 4.3.3, information on the potential remains of former trafficking of chemical warfare material needs to be made available and taken into consideration by project managers or contractors to allow for responsible planning of future harbour developments. Since harbour basins often contain metallic objects of all kinds, and in high density, it can be difficult to identify potentially dangerous single objects. If historical information suggests that chemical warfare material has been trafficked in the area, then any activities in the basin should be undertaken with the utmost care.

Apart from objects that have been lying in harbours for decades, there is also risk of recently relocated materials being brought into the harbour by fishermen, possibly even without recognizing the hazards posed by some inconspicuous object in their nets. One such dangerous relocation case occurred on 4 April 2001 when the crew of a trawler outside the coast of Blekinge (Sweden) found a bomb containing sulfur mustard in their fishing net and transported it to the harbour of Nogersund. The bomb was placed on the jetty and had to be dealt with immediately by the authorities.

4.3.5 Rescue and emergency services

Since all Contracting Parties to HELCOM provide services in the event of contamination with chemical, biological, radioactive or nuclear (CBRN) hazards on land, in principle all necessary scientific knowledge, technical equipment and trained personal should also be available in case of an incident offshore. However, many deficiencies have been identified in the emergency services' abilities to adequately respond to encounters with chemical warfare materials at offshore construction sites. For this reason, the CHEMSEA project (*cf.* Chapter 2.3.2.2.2) has decided to draft recommendations for a state-of-the-art response system based on shared examples of best practice. The results will be taken into account in the future work of HELCOM.

4.3.6 Recreational divers

Wrecks in general - also those from WWII - are of special interest to recreational divers. Most chemical munitions were dumped in the Baltic Sea at depths exceeding 80 m, mostly by item-by-item disposal and are located well away from the coastline and therefore are not easily accessible to recreational divers. The wrecks of the barges sunken in the area south of the Little Belt have been relocated and the materials recovered in the late 1950s (*cf.* Chapter 3.2.1). Of special concern, however, are the scattered single objects stemming from item-by-item disposal en route from the loading harbours to the formerly designated dumping areas (Flensburg ↔ south of Little Belt; Wolgast ↔ Gotland Deep; Wolgast ↔ Bornholm Deep) and in the area south of the Little Belt. Since these objects are not associated with a landmark of interest like a wreck, it is unlikely that these scattered chemical warfare materials will be found unintentionally in these shallower waters. However, novel, highly-sophisticated and affordable equipment enables even non-professional divers to conduct ever deeper dives, which increases the likelihood of divers or their equipment coming into contact with chemical warfare materials. Therefore, easily accessible public information of the dangers associated with sea-dumped warfare materials should also be targeted to raise the awareness of this special risk group.

4.3.7 Beach visitors

Today, the likelihood of beach goers coming into direct contact with chemical warfare materials (not including the incendiary agent white phosphorus) is negligible. However, even though the number of encounters is very low, the consequences of such an encounter are disproportionately high due to the severe consequences for the affect individual (Figure 44). This requires that responsible authorities take appropriate action to prevent similar incidents from occurring in the future.

In July 1955, 102 children from a holiday camp were injured while playing with a barrel they found on a beach at Darłówko, Poland (south-east of Bornholm, roughly half-way between Wolgast and Gdynia). The partly corroded barrel was leaking its brown-black contents of liquid sulfur mustard and at least four children suffered severe injuries, especially irreversible eye damage. The beach was closed down immediately after the incident and decontaminated during the following seven days using three tonnes of chlorinated lime. After three months, the beach could be re-opened after laboratory tests confirmed that no toxic material remained (Szarejko & Namieśnik 2009).

The high likelihood of confusing the incendiary agent white phosphorus with the collectible amber and its high occurrence at some sites (e.g., beaches of Usedom and off Liepāja) has been described in Chapter 3.2.5, Chapter 4.2.1.4 and Annex 7.1. It is seen as the special responsibility of local authorities governing the area of known hot spots to raise public awareness by clear and precise information for both beach goers and amber collectors. It should be clearly advised that before storage, amber should be collected in fire-proof metal containers and allowed to dry and heat up to 30°C when any white phosphorus mistakenly collected will ignite. If white phosphorus is found, the area must be cordoned off and the authorities contacted. Further information for collectors who have been in immediate contact with white phosphorus should be included in the emergency operation procedures. Medical personnel in the wider area of concern also need to be aware of the special toxic dangers posed by white phosphorus and not just the obvious, severe burn injuries.

Figure 44. A typical pattern of burn injuries of an amber collector who accidentally pocketed an incendiary agent instead of amber – burns on thighs because it had been pocketed and on hands because of the attempts to put the fire out. (Picture source: T. Nowotny, University Hospital Greifswald, Germany).

Since there is also a risk of encountering conventional munitions on beaches, beach maintenance employees and life guards should receive training and public awareness increased through clear warning signs. The implementation of munitions-related topics within the voluntary eco-label “Blue Flag” (www.blueflag.org) might introduce a top-down strategy for further improvements in how to deal with the legacy of war in present times.

4.3.8 Seafood consumers

As pointed out in Chapter 4.3.1, the highest likelihood of getting into direct contact with chemical warfare materials in the Baltic Sea is through commercial fishing. Consequently, there is also a risk for any fish netted with the warfare materials to be contaminated (e.g., with small lumps of potentially sticky sulfur mustard, Figure 45). When this occurs, the authorities must be alerted, the fishing gear decontaminated and the whole catch destroyed. As mentioned in Chapter 3.3, some constituents of chemical warfare materials have the potential to biomagnify within the food web. This has been assessed to potentially affect commercially valuable and primarily sediment-active top-predators such as Baltic cod. This species is also of particular concern since the Bornholm dumpsite is located in one of its main breeding areas and offers rich fishing grounds (Niiranen et al. 2008).

Figure 45: Lumps of solidified sulfur mustard and the metal parts of a Spray Can 37 mine trawled up with a catch that was later discarded (Picture source: Maritime Surveillance Centre South on Bornholm).

No parent chemical warfare agent-associated compounds have been detected in Baltic Sea fish. Based on models results, Sanderson et al. (2009) assessed the maximum recommended monthly amount of fish servings[3] stemming from the primary dumpsites/no-fishing zones in the Bornholm dumpsite to be zero to one. This assessment was based on extreme worst-case assumptions, taking into account the load of arsenic-containing chemical warfare agents dumped in the area, but not specifically addressing all potential transformation or break-down products. Their study concluded that there was a need for further empirical research, especially regarding the speciation of arsenicals in fish and their carcinogenesis as well as the effects of human exposure to sulfur mustard via seafood.

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[3] *Serving size* is the amount of a food or drink that is generally served; fish serving size = 85-150 g on average

Studies aiming specifically at the genotoxicological effects of chemical warfare agents are still on-going within the CHEMSEA project (*cf.* Chapter 2.3.2.2.2 and Torre et al. 2013).

The possibility of sulfur mustard poisoning occurring via seafood consumption is supported by newspaper reports stemming from the late 1940s (June 1948, April 1949). It was reported that some Danish and German seafood consumers had become ill after eating fish caught in the area of the Bornholm dumpsite - cod roe later assessed by medical staff was found to contain sulfur mustard (HELCOM 2011a). However, the exposure occurred due to mechanical mixture of warfare compounds with fish roe that was consumed. Bottom-dwelling fish chronically exposed to chemical warfare agents due to their on habitat association in vivo in a dumpsite in the Mediterranean Sea off Bari, Italy, have been shown to carry obvious signs of biomarker responses; however, no chemical warfare agents were found in the fish flesh and thus any skin diseases, parasite infestation and general low health could be connected to overall environmental stress factors. Further research in this field was recommended by the authors (Torre et al. 2013). While no specific analysis for the presence of warfare material constituents is conducted, it is unlikely that seafood showing such signs would go unnoticed in the sorting stage and reach the customer.

4.4 Hazards and threats to the marine environment

As discussed in Chapter 3.3, the hazards posed by the constituents of chemical warfare materials to the marine environment have many facets. In addition to the obviously detrimental effects of direct contact with active chemical warfare agents, all pathways of associated chemical compounds into and within the marine food web as well as the multiple biological symptoms related to acute and long-term exposure to toxic substances need to be considered. Heavy metals, arsenical compounds, explosives, persistent chlorinated compounds and other artificial compounds (xenobiotics) are of special concern and require consideration.

Most of the areas formerly used for dumping warfare materials are rather deep basins that act as sediment traps, are dark and most of the time cold and poorly oxygenated (*cf.* Chapter 4.2.1.3). Taking this into account, the logical conclusion is that biological activity in the designated dumping areas might be low and therefore the intake of toxic substances into the marine food web is not significant. However, increasing scientific knowledge on the natural processes in the deep water zone of the Baltic Sea contradicts from this assumption. Moreover, the findings of Feistel et al. (2004) on the inflow of warm water into Baltic Sea during the summer 2003 and the long-term influence it had on the Baltic deep basins (*cf.* Chapter 4.2.1.3) raises more questions on possible biological activities in the vicinities of dumped chemical munitions (Sanderson et al. 2009).

4.4.1 Chronic effects

Fish, marine mammals and sea birds may come into direct contact with the chemical warfare materials themselves (e.g., leaking munitions or lumps of chemical warfare agent) or via contaminated food., Such direct contact with active chemical warfare agents will likely result in chronic toxic effects which manifest as behavioural changes and superficial injuries (e.g., skin blisters and lesions from contact with sulfur mustard).

The development of blisters on the skin or mucous membranes of fish and marine birds and mammals are seen as the most obvious effects of contamination with blistering agents. However, the occurrence of skin blisters is rather common and the cause may also be other than exposure to chemical warfare agents, such as an infected injury or reaction to other hazardous substances. Tests to determine the toxic effects on fish have shown that mustard gas concentrations of 10 ppm have a lethal effect in eels but not in flounders (NATO/CCMS, 1995).

While similar studies for the Baltic Sea are still on-going (e.g., within the CHEMSEA project, *cf.* Chapter 2.3.2.2.2), research into the exposure of benthic fish species permanently inhabiting a dumpsite in the Mediterranean Sea off Bari, and sometimes even within the chemical munitions themselves, highlight the difficulties associated with conducting habitat-scale analyses or ecosystem assessments. Even though the observed state of illness – mainly skin lesions and blisters - suggest that it might be attributed to the blistering agents present at the site, from a scientific perspective the authors could only attribute those observations to be 'reasonably' ascribable to compounds leaking from the corroded munitions (Torre et al. 2013, *cf.* Chapter 4.3.8).

Russian studies on the toxicity of low concentrations of mustard gas (0.33 mg/L and 0.0033 mg/L) presumed to be present in bottom water over dumped munitions, showed toxic effects in zooplankton (*Daphnia Magna*) but no acute toxicity to gastropods and fish. Similar concentrations found over Adamsite and chloroacetophenone munitions produced no acute toxicity in the above-mentioned organisms (Gorlov et al. 1993). Other studies on the subject have also been carried out based on measured or modelled effect-concentrations (Sanderson et al. 2007), showing that environmental risks towards the fish community in the Bornholm Basin from dumped chemical warfare materials cannot be ruled out by decreased solubility of chemical warfare agents.

A severe injury and subsequent infection may cause the death of a wild animal. Determining whether an infected injury is related to exposure to an active chemical warfare agent is difficult at best, and identifying the actual cause of death of a decomposing body found on a beach is even harder. As post mortem examinations of marine animals typically point to more than one possible cause of death, statistics on cause of death tend to be unspecific.

4.4.2 Long-term effects

Like humans, larger and long-lived forms of marine life suffer from chronic diseases like cancer or genetic defects after having been in exposed to low doses of toxins over a long period. The impacts of long-term effects are often gradual and may remain hidden inside a population. They are difficult to diagnose and correlate to a single cause-and-effect relationship. While the influence of chemical warfare agents cannot be completely excluded, natural and other anthropogenic pressures must also be considered. However, a definite and unequivocal identification of a single impact is often difficult to obtain.

Preliminary results obtained from the studies carried out within the CHEMSEA project (Lehtonen et al. 2013), showed lower fitness, an elevated prevalence of bacterial skin ulcers and gill parasites (*Loma sp.*), a higher degree of head kidney pathology and a higher degree of genotoxic effects in fish caught in the dumpsite area compared to the control areas. Moreover, comparatively low lysosomal membrane stability, possibly attributed to arsenic stress, was found both in fish and in the blue mussel caging study in the 'hot spot' area of the Bornholm deep compared to the reference area.

Compounds stemming from chemical warfare agents have been detected in sediment and pore water samples in the wider area of the Bornholm dumpsite (*cf.* Chapter 3.3, Missiaen et al. 2010, Sanderson et al. 2010, Nord Stream AG 2011c). Conservative model-based assessments on the environmental risks to fish from the sea-dumped chemical warfare materials in the Bornholm Basin dumpsite conclude that primarily sediment-active species (e.g., sole) and omnivorous fish (e.g., cod) would potentially be at risk, whereas primarily pelagic species (e.g., *Salmonidae*) would be at a lower risk, assuming an extreme worst case scenario. Clark-type warfare agents, especially triphenylarsine as a constituent of arsine oil (technical-grade Clark I), were identified along with Adamsite and sulfur mustard as compounds of special concern (*cf.* Annex 7.1) (Sanderson et al. 2008). Based on various sources, Sanderson et al. (2008) derived Toxic Units which represent the combined risk toxicity of chemical warfare agent compounds to the fish present in the primary and secondary dumpsites in the Bornholm Deep. The risk to the fish community under the more realistic Scenario B is marginal (TU< 0.2) in a 4-metre thick layer and 58 km down current (Figure 46) (Sanderson et al. 2008, and references therein). These figures, however, represent modelled concentrations and may be underestimated in individual cases.

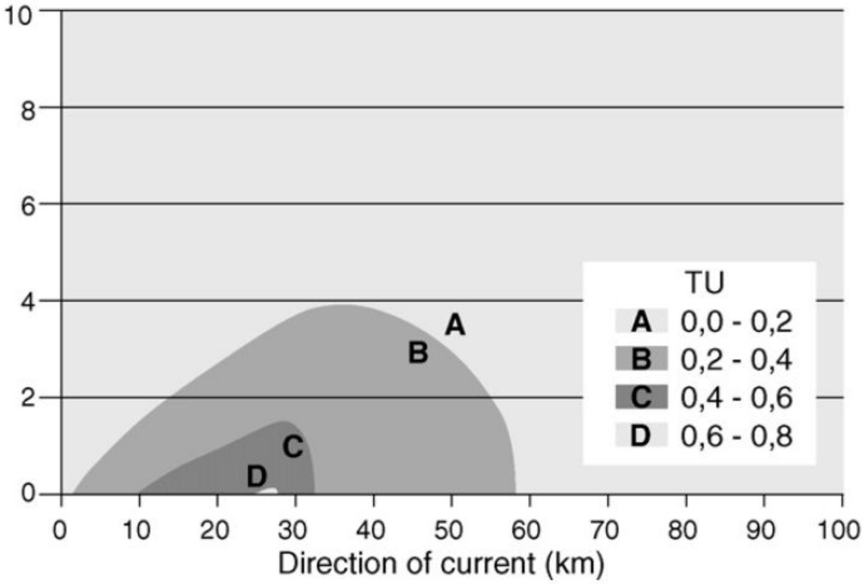


Figure 46. Total CWA mixture risk (TU) volume in seawater in primary and secondary dumpsites (After: Sanderson et al. 2008).

Preliminary studies aiming at an environmental risk assessment for the western part of the Lithuanian EEZ, which overlaps with the dumpsite in the Gotland Basin, found that the studied parameters - arsenic contamination, arsenic-tolerant bacteria and zooplankton - did not produce well-defined responses concerning potential risks. More specifically, the need for the determination of individual chemical warfare agent signature compounds at dumpsites was identified as a prerequisite for the evaluation of potential environmental risks (Garnaga & Stankevičius 2005).

A different environmental marker for the presence of sea-dumped warfare materials was found by researchers detecting and isolating bacterial strains tolerant to the hydrolysis products of sulfur mustard (Medvedeva et al. 2009). The isolated strains were cultivated in the laboratory and were shown to be capable of biodegrading thiodiglycol-type compounds stemming from abiotic hydrolysis of sulfur mustard, even at low temperatures (5 °C). Bacteria with these capabilities were found to occur to an unusual degree in the centre of the designated dumping area off Bornholm and in the dumpsite of the Gotland Basin. These bacteria represented up to 85% of all heterotrophic bacteria found in samples of near-bottom water less than 1 m above the seabed taken at these sites (up to 85% at the Bornholm site; up to 20% at the Gotland site). While these bacteria usually only comprised 0.5% of all bacteria counted in the samples, it needs to be noted that the occurrence at a reference site outside the known dumpsites was determined to be 3% of all heterotrophs. In samples with a higher percentage of these tolerant bacteria, a diminished diversity of bacterial species was also found. The enriched presence of the specialized bacteria was attributed to the occurrence of sulfur mustard-type warfare materials known to have been dumped in the areas under investigation. The authors of the study concluded that the results suggest the potential for the self-purification of contaminated water and sediments by natural populations of microorganisms (Medvedeva et al. 2009). The fact that none of these specialized bacteria were found in water samples taken above 1 m over the seabed, underlines the limited stability of sulfur mustard when it is dissolved in seawater. It needs to be noted, however, that these findings do not diminish the hazards posed by persisting solidified sulfur mustard-type materials formed by aging processes or stemming from special tactical mixtures. It is unclear to which extent microbial degradation can assist in breaking down and detoxifying the chemically self-contained lumps of sulfur mustard encased in a protective layer of polymerized material and consisting of undiluted and most likely also active agent (*cf.* Annex 7.1).

While no major impacts on the marine environment of the Baltic Sea as a whole are currently discernible, there is also no clear picture on the potential and future long-term effects of sea-dumped warfare materials. The legacy from the past is still resting on the bottom of the sea and is inextricably linked to the fish of today, and it may be that its effects will only be discernible on the consumer of tomorrow.

5 Conclusions and recommendations

Chemical warfare materials are scattered within and in many cases outside the designated Baltic Sea dumping areas. In addition to the dumping areas marked on sea charts, chemical warfare materials were also disposed of item-by-item en route from the loading harbours (e.g., Wolgast and Flensburg) to the designated dumping areas. Moreover, there are some beaches in the southern Baltic Sea which are occasionally contaminated with white phosphorus stemming from incendiary munitions.

Because of the scarcity of information on the dumpsite off Måseskär bordering the Helsinki Convention Area, further national and/or international studies are needed (e.g., in cooperation with OSPAR).

There still remains uncertainty on the amounts and locations of dumped chemical warfare materials; however, during the course of preparing this updated HELCOM report on sea-dumped chemical munitions some additional information became available and provided clarification for certain areas and operations. In most cases, the available information on dumping activities originates from official summary reports from the time of manufacturing chemical warfare materials, or is based on estimates deduced from official documents or officially documented follow-up accounts. Rarely is gapless and precise information available from official correspondence that must have accompanied the activities of trafficking chemical warfare materials over land, in harbours and at sea.

In accordance with the 1994 CHEMU Report, it is re-confirmed that a total of 40,000 tonnes of chemical warfare materials were dumped. Recent archive investigations indicate that the amounts of chemical warfare agent mixtures contained in them was 15,000 tonnes, which is slightly more than estimated earlier (13,000 tonnes, BSEP 64B, HELCOM 1996).

Sulfur mustard mixtures represent about 63% of all materials dumped near Gotland and Bornholm. However, probably due to the formation of persistent lumps, this hazardous material is involved in 88% of all reported fishing incidents. Sulfur mustard poses a present risk to humans who come into direct contact with it and to organisms within its immediate vicinity. In comparison with the situation at the time of the 1994/1995 HELCOM CHEMU reports, the amount of active chemical warfare agents has decreased as a result of the corrosive disintegration of munitions casings and the ensuing release and possible concomitant degradation of chemical warfare agents. In addition, a small amount of warfare materials has been removed (e.g., caught by fishermen and destroyed by the authorities).

According to existing knowledge, chemicals originating from chemical warfare materials can spread out from the location of the containers through natural and anthropogenic processes. Varying stages of contamination by chemicals, presumably originating from chemical warfare materials, have been found in sediments in and in the vicinity of the dumping grounds.

Arsenic-containing warfare agents have been shown to contaminate areas of the sea bottom and to spread both within and outside the dumpsites. However, in all cases investigated to date, no chemical warfare agent parent compounds or degradation products were detected in the water column in measurable quantities. The environmental impact of chemical warfare agents has been assessed by ecotoxicological means and by theoretical considerations; however, little is known about the magnitude of the effect of different chemical warfare degradation products on the marine environment.

The general recommendations of the 'Final Report of the ad hoc Working Group on Dumped Chemical Munitions (HELCOM CHEMU) to the 16th Meeting of the Helsinki Commission (1995)' are considered to be valid, but are superseded by the HELCOM MUNI recommendations given in this report.

Especially taking into account the continuously increasing scientific knowledge and new information resulting from previous and on-going activities of the Contracting Parties (e.g., Lithuania, Poland and Germany), the HELCOM MUNI expert group was of the opinion that the formerly drawn conclusions and recommendations need to be re-adjusted in order to adequately reflect the current state of knowledge.

Although dumped chemical munitions were recovered in the 1960s, in 1995 HELCOM recommended that chemical munitions should not be recovered due to their degraded state and the lack of suitable technological solutions for safely removing and destroying them. Even today, the risks associated with handling them are still high.

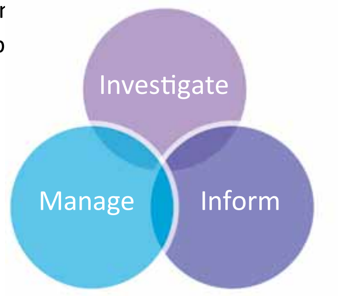
For people working in the marine environment of the southern and western Baltic Sea (e.g., fishermen or workers involved in offshore construction activities), the risk of encountering chemical warfare materials cannot be ruled out.

With regard to the increasing utilization of the seafloor for economic purposes (e.g., offshore wind farms, sea cables, pipelines), the risk of encountering sea-dumped munitions is increasing. Furthermore, white phosphorus has been found washed up on the beaches of the southern Baltic Sea. This incendiary agent constitutes a risk for beach goers.

Taking into account the advancement of technological options developed in the context of the offshore oil and gas industry over the past decades, as well as existing means for professional, efficient and safer disposal of chemical warfare materials, the option of recovering dumped chemical munitions should no longer be entirely excluded; rather, it should be considered as an option on a site-specific basis, when applicable, and in accordance with nationally accepted guidelines or the results of risk assessments.

As the Contracting Parties are conducting various activities nationally and internationally, and thereby adding to the existing state of the knowledge on dumped chemical warfare materials in the Baltic Sea ar impacts on the ecosystem, this report should be up when significant new findings become available.

The HELCOM CHEMU recommendations from 1994/1995 have been reviewed and updated as follows and arranged into three groups:



Investigate

- **Historical Research** - new or additional information on the dumping of chemical warfare materials and the possible co-disposal of conventional munitions in the Baltic Sea is likely to be obtained by archival research as shown by the information on en route dumping in the Flensburg Fjord.
  The Contracting Parties are encouraged to carry out, support and facilitate historical research in national and international archives, especially to undertake efforts to get access to still classified documents of relevance e.g., in the archives of the WWII Allies.
- **Technical Research** – precise, site-specific data on the types, quantities, status and spreading of sea-dumped warfare materials and their constituents in the Baltic Sea.
  The Contracting Parties are recommended to carry out, support and facilitate technical research, e.g. within international projects, in known and suspected areas using technology specifically suitable for the task.
- **Research Transfer** – inter-regional sharing of information would increase the overall knowledge regarding the issue; technical research is needed to complement historical data to allow for well-informed risk assessments. Likewise, single findings of warfare materials should be cross-checked with historical references.
  The Contracting Parties are recommended to share detailed information on the findings both within and outside the Baltic Sea region taking into account the UN General Assembly Resolution A/RES/65/149. Furthermore, it is advisable to investigate dumpsites bordering the Helsinki Convention Area, e.g. the dumpsite off Måseskär.

Manage

- **Analytical Capability** – the further development of chemical analytical methods is needed as well as updating the ecotoxicological and physicochemical properties assessments.

  The Contracting Parties are recommended to support and facilitate the development of suitable analytical methods and improving analytical capabilities.
- **Periodical Surveys** - guidelines for the periodical performance of intrusive/ non-intrusive sampling and testing of suitable methods both in known and suspected dumpsites are necessary in order to establish trends and foresee possible changes in the environment in these areas.

  The Contracting Parties are recommended to support and facilitate the development of suitable guidelines for carrying out surveys and testing methods.
- **Risk Assessments** - suitable instruments and methods for site-specific risk assessments of selected dumpsites should be developed, taking into account the threats to humans and the marine environment, including possible acute, chronic and long-term effects.

  The Contracting Parties are recommended to support and facilitate the development of suitable instruments and methods for site-specific risk assessments.
- **Intentional Recovery** - with regard to the increasing use of the seafloor, the intentional recovery of chemical warfare materials, where applicable, might no longer be excluded as a site-specific management option in accordance with nationally accepted guidelines or the results of risk assessments, as seen in other areas for chemical munitions dumping.

  The Contracting Parties are recommended to transfer procedures and experiences for intentional recovery that exist under the provisions of current international legal instruments.
- **Unintentional Catches** - risks associated with unintentional catches of chemical warfare materials are still present for the crews of fishing vessels operating in the vicinity of dumping areas.

  The Contracting Parties are recommended that response teams should be deployed and that on their advice relocation of caught chemical warfare material may be considered as an acceptable emergency measure.

Inform

- **Document Updating** - with regard to on-going national and international activities and projects, periodical updates of the HELCOM report on dumped chemical warfare materials will become necessary.
  The Contracting Parties are recommended to consider this report as a step in an on-going process and to establish a working process for periodical updates after significant new information becomes available.
- **Public Awareness** - up-to-date information on sea-dumped warfare materials, including white phosphorus in the Baltic Sea region, and on-going activities should be provided via easily accessible public information at national and HELCOM levels, taking into account UN General Assembly resolution A/RES/65/149. Furthermore, specific local information should be available in areas of concern for the possible occurrence of white phosphorus such as tourist information leaflets and warning signs.
  The Contracting Parties are recommended to support and facilitate the development and operation of such information portals and other relevant measures to increase public awareness.
- **Knowledge Provision** - national centres or responsible organizations for the collection of information on sea-dumped warfare materials, the coordination of response and training activities for the decontamination of vessels and equipment, as well as the treatment of affected people are necessary.
  The Contracting Parties are recommended to support and facilitate such national centres.
- **New Guidelines** - increasing use of the seafloor for the construction of offshore facilities, such as wind farms and sea cables, bring new groups into potential contact with sea-dumped chemical and conventional munitions, necessitating new and updated guidelines for possibly affected groups. When active in the vicinity of areas with known or suspected contamination by chemical warfare materials, contingency measures for dealing with both chemical and conventional warfare materials should be in place.
  The Contracting Parties are recommended to carry out, support and facilitate the update and development of suitable guidelines for all potentially affected groups.
- **Up-to-date Charts** - technical investigations have provided and are still providing information on the actual positions of sea-dumped chemical munitions. No special code for chemical warfare materials will be available for future Electronic Nautical Charts.
  The Contracting Parties are recommended to update sea charts to reflect the extensions of primary and secondary dumpsites, and to ensure that no information is lost on nautical charts when the transition to Electronic Nautical Charts is made.

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7 Annexes

7.1 Chemical warfare agents and associated compounds

The chemicals used in the chemical warfare agents have certain reactivities and physicochemical properties, resulting in the observed biological effects relevant for military usage. Those properties vary widely among the group of chemical warfare agents and have been described under laboratory conditions for pure compounds. In addition, the incendiary agent white phosphorus is taken into account (*cf.* Table 6).

Table 6: Simplified overview of the physicochemical properties of pure substances under ideal laboratory conditions and selected remarks pertaining to their behaviour under Baltic Sea conditions. Compiled from the U.S. Army 1996, ATSDR et al. 1997, Munro et al. 1999, Sanderson et al. 2008, Bizzigotti et al. 2009 and Missiaen et al. 2010. The octanol/water-partition coefficient (log K_{OW}) reflects the tendency of the compound to bioaccumulate (without taking transformation or decomposition reactions into account) and the organic carbon-partition coefficient (log K_{OC}) is given as an estimate of the tendency to bind to soil or sediment.

Compound	Water solubility	log K_{OW}	log K_{OC}	Melting points (°C)	Boiling point (°C)	Density (g/cm^3)	Remarks
Sulfur mustard	0.9 g/L	2.4	2.3	14.5	228	1.27	solidifies to insoluble lumps and can be netted
Nitrogen mustard	0.16		2.8	-3.7	235	1.24	
Lewisite	low / transf.			-18	190	1.89	
Adamsite	0.4 mg/L	4.1	3.7	195	410	1.65	occurs as solid and can be netted
Clark I	2 g/L	4.5	4.3	38–44	307–333	1.39	
Clark II	2 g/L	3.3	3.8	30–35	290–346	1.33	
Phenyldichloroarsine	0.6 g/L	3.1	2.9	-15.6	257	1.66	cf. arsine oil
Triphenylarsine	very low	6.0	5.6	60	360	1.22	cf. arsine oil
Trichloroarsine	2.3 g/L	1.6	1.5	-16	130	2.16	cf. arsine oil
α-Chloroacetophenone	<<1.6 g/L	1.9	2.0	58-59	244	1.26	occurs as solid and can be netted
Phosgene	low / dec.			-118	8.3	1.41	
Diphosgene	low / dec.			-57	128	1.65	
Tabun	98 g/L	0.3	1.7	-50	247.5	1.10	
Hydrogen cyanide	95 g/L	-0.7	0.4	-13.4	25.6	0.69	
White phosphorus	4.1 mg/L	1.2	3.0	44.1	280.5	1.83	occurs as solid and can be washed up onto beaches

As the bulk of chemical warfare agents were produced and stockpiled for military use, the purpose of the weapons-grade products was to have their intended effects during military applications and, therefore, they were not as pure as research-grade materials. Often technical-grade products with chemical impurities were used (e.g., technical Clark I: arsine oil). Valuable materials were sometimes diluted with solvents (e.g., Tabun with chlorobenzene) and tactical mixtures were prepared with additives influencing melting point, viscosity and the dwelling time of the warfare agent. The aromatic and chlorinated compounds used as solvents (e.g., benzene, chlorobenzene, tetrachloromethane) are also of environmental concern. The problem of persistent organic and possibly chlorinated compounds stemming from anthropogenic sources is well-known – a fact that should be noted but is not described here in detail.

The properties and the behaviour of pure agents under laboratory conditions are important factors to be taken into consideration for the assessment of sea-dumped chemical warfare materials; however, they do not fully reflect the complex behaviour of chemical warfare agent mixtures produced and dumped decades ago. Moreover, in addition to the chemical warfare agent payloads discussed here, dumped chemical munitions objects also contain explosives, which have the potential to leach toxic, persistent and biomagnifying substances (Juhasz & Naidu 2007, Lotufo et al. 2009). While systematic studies of the environmental fate of chemical munitions and aged chemical warfare agent mixtures under natural conditions in the sea are lacking, an evaluation of the environmental fate of chemical warfare agents and associated compounds can, however, be deduced from compounds detected in environmental samples and from the state of intentionally or accidentally recovered materials (e.g., lumps of sulfur mustard).

The behaviour of chemical substances in the marine environment depends both on the substance itself, its reactions in the environment (e.g., degradation by abiotic reactions or due to the activity of microorganisms) and the physicochemical properties of the chemical and its degradation products. While transformation and degradation reactions can also occur in hermetically sealed containers (e.g., formation of sulfur mustard lumps), exposure to water and dissolution of the chemicals can be seen as the most crucial step towards degradation (e.g., by hydrolysis or oxidation). Under the complex influences and conditions in the marine environment, the maximum reachable concentration of chemical warfare agent in seawater will be less than its theoretical solubility under controlled laboratory concentrations. As a result of further dilution and transformation reactions, the occurrence of high concentrations of an active agent in the seawater is unlikely. Furthermore, in general, the hydrolysis products of chemical warfare agents are less toxic than the parent agents with the exception of the transformation products of Lewisite. However, bioaccumulation of compounds can occur at any ambient concentration below the acutely fatal level and with any compound exhibiting the relevant tendencies.

7.1.1 Sulfur mustard

Sulfur mustard (also known as mustard gas, yperite, H or HD) is an oily liquid with bis(2-chloroethyl)sulfide as its main active component. While acute effects include severe blistering of the skin, the delayed effects after exposure include cancer. Due to its high chronic toxicity, sulfur mustard has been assessed to be among the most risky chemical warfare agent-related compounds with regard to the potential human consumption of contaminated fish (*cf.* Chapter 4.3.8) (Sanderson 2009). Since the melting point of the pure compound is quite high (14.5 ˚C, *cf.* Table 6) (Bizzigotti et al. 2009), tactical mixtures containing approximately 25% of organic solvents (e.g., benzene, chlorobenzene and tetrachloromethane) have been produced (Martinetz & Rippen 1996), further lowering the melting point of the weapons-grade material and allowing for its use at lower ambient temperatures (German WWII winter-grade sulfur mustard, ‘Winterlost’). In addition, winter-grade mixtures with the phenyldichloroarsine (‘Pfiffikus’), also occurring in technical Clark I, have been described (Maynard 2007). At least 20% of all sulfur mustard mixtures produced were winter-grade. Another important type of tactical mixture was sulfur mustard with additional thickening additives (e.g., 41.5% sulfur mustard and arsine oil each, with 17% of organic thickeners such as poly(methyl acrylate), lignite wax or chlorinated rubber) (Martinetz & Rippen 1996), making the mixture very viscous, tenacious and more persistent (‘Zählost’).

While pure sulfur mustard degrades fairly fast in fresh water, under laboratory conditions it also degrades quite rapidly in seawater (half-life of 175 minutes at 5 ˚C) (Bizzigotti et al. 2009). However, sulfur mustard mixtures are known to have persisted in the marine environment for decades. One factor contributing to this is the presence of virtually insoluble additives and thickeners in the tactical mixtures produced. Moreover, due to the aging process in the container, polymeric material and solid salts (e.g., ‘mustard heel’) are formed on the surface of the liquid or semi-liquid agent mixture (Bizzigotti et al. 2009). Solidification and the formation of a polymeric material are also induced by limited contact with water (e.g., superficial wetting of the payload inside a container disintegrating due to corrosion). Accordingly, the formation of solidified lumps can even occur in weapons-grade sulfur mustard without additional additives or thickeners (summer-grade sulfur mustard, ‘Sommerlost’) (Munro et al. 1999). The outer layer of the insoluble solidified material conserves the active agent inside the lump and protects it from further degradation by hydrolysis.

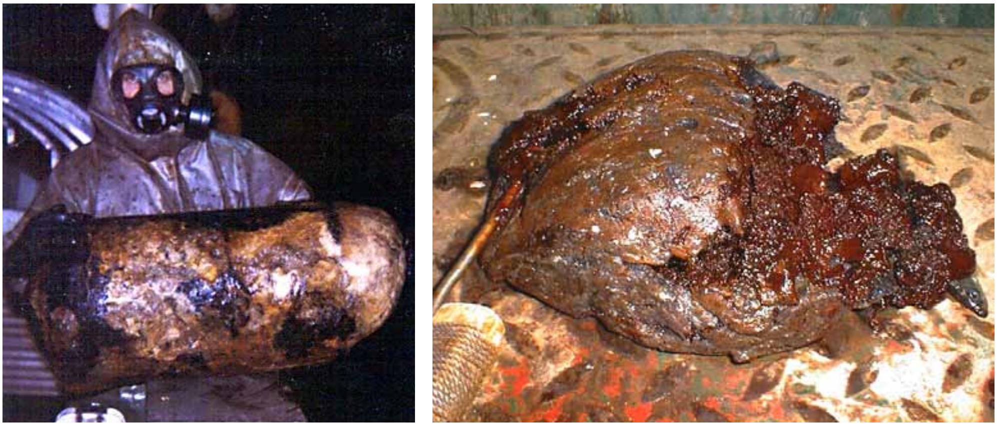


Figure 47: Lumps of solidified sulfur mustard trawled up by fishermen in the waters around Bornholm (left). The 70 kg lump retained the original shape of the KC250 bomb and supposedly contained the bursting charge with 15 kg of explosives inside. The 3 kg lump was found by R/V 'Dana' in 2001 and it could not be ruled out that it contained explosives (right). Both lumps were emergency-relocated (*cf.* Chapters 3.2.3.3 & 4.3.1) (Picture source: Maritime Surveillance Centre South on Bornholm).

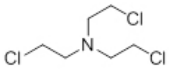
In 1997, a lump of sulfur mustard was recovered from the Bornholm Deep during the 34th cruise of RV 'Professor Shtokman'. A bucket sample (ladle) of sediments contained a substance resembling dried, spread paint which, after warming up to 30 ˚C, transformed into a gel with a pungent odour. The sample was preserved and sent to St. Petersburg for further laboratory analysis, which confirmed that it contained 3% of sulfur mustard (personal communication, V. Ivlev).

In the years 1998–1999, detailed laboratory tests of a 5-6 kg lump of sulfur mustard accidentally trawled up by fishermen on 9 January 1997 were carried out at the Military University of Technology in Warsaw (Mazurek et al. 2001). The yellow-brown lump had been hauled aboard the fishing vessel and resulted in eight fishermen being poisoned and four hospitalized. The lump was later described by the laboratory researchers to have had a 'greasy consistency' with part of it being solidified. About 50 different chemical compounds of varying toxicity were found in samples taken from the lump and in 30 cases the chemical structure could be identified. Several compounds were agents with sulfur mustard activity (e.g., sesquimustard), with the main active agent bis(2-chloroethyl)sulfide being the most abundant compound in the mix. No thiodiglycol - the product of complete sulfur mustard hydrolysis - was detected in the lump. Clark I (chlorodiphenylarsine) was also detected in the samples; however, it could not be determined whether the compound had been added in the context of a tactical mixture or was contaminated by other sea-dumped warfare materials.

Since thiodiglycol can only be formed in contact with water on the surface of the lump and is soluble in water, it will dissipate in the surrounding water. There is only one example described where small amounts of an oxidized degradation product of thiodiglycol were detected in a sediment sample taken from the highly contaminated area of the Bornholm Deep dumpsite (3.3 µg/kg dry weight of sediment) (Missaen et al. 2010, Sanderson et al. 2010). Thiodiglycol has no warfare agent activity and strains of bacteria tolerant to sulfur mustard-hydrolysis products (not resistant to active sulfur mustard agent) and capable of biodegrading the compounds have been isolated from the Bornholm and Gotland dumpsite areas (*cf.* Chapter 4.4.2) (Medvedeva et al. 2009).

Sulfur mustard is the most abundant chemical warfare agent dumped in the Baltic Sea (63% of all materials dumped according to the limited historical information given in Chapter 3.2). It has been reported among the material transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm. Chemical warfare materials filled with sulfur mustard mixtures have also been found in the harbour basin of Wolgast in 1952/1953 and 1964/1965. Among other chemical warfare agents, sulfur mustard materials discovered between 1959 and 1965 on GDR territory were transported and dumped in the waters around Bornholm (*cf.* Chapter 3.1.1). Apart from the more recent discovery of the enriched presence of special bacteria capable of degrading the hydrolysis products of sulfur mustard, it has long been known that sulfur mustard is present in the Bornholm and Gotland Deep areas and in the vicinity of the former transport routes due to catches of sulfur mustard lumps and sulfur mustard-containing warfare materials (*cf.* Annex 7.2). Sulfur mustard-type materials are also the most abundant materials reported to have been trawled up by fishermen, accounting for about 88% of all reported incidents. The catches reported since 1994 have amounted to up to 190 kg of chemical agent (*cf.* Annex 7.2 - Table 7). The five chemical munitions objects of concern discovered north-east of Bornholm during the Nord Stream pipeline construction phase were sulfur mustard-filled KC250 bombs in various states of corrosion. Lumps of sulfur mustard were detected by visual inspection with a Remotely Operated Vehicle in the vicinity of the objects (Nord Stream AG 2011a). Based on recently re-appraised historical evidence, the dumping of sulfur mustard-type materials is also suspected to have occurred in 1945 on the transport routes from Flensburg and in the designated dumping area south of the Little Belt (*cf.* Chapter 3.2.1).

7.1.2 Nitrogen mustard



Nitrogen mustard, tris(2-chloroethyl)amine (also known as HN-3), is a liquid vesicant quite similar in function and behaviour to sulfur mustard. In weapons-grade material, HN-3 is accompanied by bis(2-chloroethyl)methylamine and bis(2-chloroethyl)ethylamine (Munro et al. 1999).

Nitrogen mustard is characterized by a lower melting point (-3.7 °C) and lower water solubility than sulfur mustard, also taking longer to hydrolyze in water.

However, unlike sulfur mustard, nitrogen mustard does not form polymeric material and persistant lumps.

Nitrogen mustard was included in the 1994/1995 HELCOM CHEMU reports on the basis that its dumping in the Baltic Sea could not be excluded (assigned to the dumpsite off Bornholm as 'less certain') (BSH 1993, HELCOM 1994 & HELCOM 1995). There is currently no historical evidence or any findings of nitrogen mustard-filled warfare materials or the detection of break-down products to support this assumption.

Organoarsenic chemical warfare agents

- In principle, all organoarsenic chemical warfare agents described here (Lewisite, Adamsite, Clark types) can undergo decomposition into inorganic arsenic compounds, which can be assimilated by organisms, adsorbed to sediments and suspensions, desorbed, transported in the water column and transformed into other inorganic or organometallic species (Maher & Bultler 1988).
- Depending on the chemical 'wrapping' the arsenic atom in the species is surrounded with (e.g., oxidation state), toxicity may either be pronounced or even negligible (e.g., arsenobetaine), but very much unlike the original warfare agent activity (Leermakers et al. 2006, Sharma & Sohn 2009).
- Arsenical chemical warfare agents have been assessed to be potentially risky with regard to the possible consumption of contaminated fish by humans, even though only toxicity data of inorganic arsenicals was available and used as a proxies (cf. Chapter 4.3.1.8) (Sanderson et al. 2009).
- However, an elevated total arsenic level and any (organo)arsenic species occurring naturally cannot be ascribed beyond doubt to chemical warfare agents. Natural and industrial sources must also be considered (Garnaga & Stankevičius 2005).
- The breakdown products of organoarsenic compounds still containing structural elements of the parent warfare agents, e.g. phenyl rings, are generally of greater concern regarding toxicity, persistence and bioaccumulation (Kroening et al. 2009).

Figure 48: A note on the nature and environmental fate of organoarsenic chemical warfare agents.

7.1.3 Lewisite

Lewisite (dichloro(2-chlorovinyl)arsine, also designated Lewisite I), is a liquid organoarsenic vesicant. Weapons grade-material used in chemical munitions contained impurities, making it appear as a yellow or brown liquid, typically also containing some 10% of Lewisite II, (chlorobis(2-chlorovinyl)arsine), small amounts of Lewisite III (tris(2-chlorovinyl)arsine) and trichloroarsine (Haas et al. 1998a).

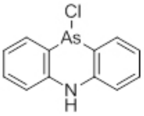
Lewisite reacts with water to form 2-chlorovinylarsinous acid, which can be further transformed to 2-chlorovinylarsinic oxide. Both of these transformation products have vesicant properties similar to Lewisite and are suspected to be the actual effect-causing compounds when humans are exposed to Lewisite. Furthermore, even after storage in seawater at 0 °C for 10 weeks, the vesicant properties of a Lewisite mixture were reported to remain unchanged (Bizzigotti et al. 2009).

The blistering agent Lewisite was listed in the 1994 HELCOM CHEMU report among the chemical warfare agents produced by Germany during WWII as ‘production small, but unknown’. Furthermore, Lewisite was given as an example for additives used for lowering the melting point of sulfur mustard in tactical mixtures for low temperature ambient conditions (winter-grade sulfur mustard, ‘Winterlost’) (HELCOM 1994). The former statements need to be re-adjusted with respect to more recent findings.

Lewisite had been produced by Germany for testing and evaluation in 1917 – and found wanting. While it cannot be ruled out that some small quantities had been produced for testing during WWII, there is currently no credible evidence that these materials had been stockpiled by Germany (Vilensky & Sinish 2004). This is also supported by the fact that no designation and marking code for Lewisite or its mixtures existed in the German marking system for WWII munitions (U.S. Army 1994). However, Lewisite and associated tactical mixtures had been produced and stockpiled by other countries (e.g., Japan, UK, USA, Soviet Union) during WWII (Vilensky & Sinish 2004) and Lewisite-filled chemical munitions found on German territory in the post-WWII period were of foreign origin (Haas 1997).

While the origin of the material remains unclear, the presence of Lewisite warfare materials has been verified in areas surrounding the dumpsite east of Bornholm by chemical analysis. A distinctive derivative compound of weapons-grade Lewisite was detected in sediments in trace and quantifiable amounts following the chemical inactivation treatment of the samples (Nord Stream AG 2011c).

7.1.4 Adamsite



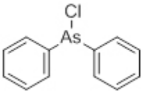
Adamsite (diphenylaminechloroarsine, also known as DM), is an arsenic-containing irritant chemical classified as a nausea or vomiting agent. It appears as a crystalline substance, is readily soluble in organic solvents but nearly insoluble in water. In German artillery shells, Adamsite was used either mixed with nitrocellulose powder (50%) or as solid material in a container encased by a surrounding explosive. Mines contained a burning Adamsite ‘candle’. However, the materials dumped in the waters off Bornholm and Gotland were reported to have mostly consisted of Adamsite filled into bombs and wooden crates (*cf.* Chapter 3.2.2 and Chapter 3.2.3).

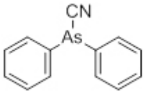
Adamsite hydrolyzes into phenoarsazin-10(5H)-ol and hydrochloric acid. The degradation of Adamsite is slower than that of the arsenic- and phenyl moietiescontaining Clark-type agents. Consequently, similarly to Clark-type agents, degradation products are persistent and have a pronounced bioaccumulation potential due to their lipophilicity. In a sampling campaign targeting the wider area of the Bornholm dumpsites, oxidation products of Adamsite were also detected well outside of the former munitions dumping grounds marked on sea charts and was assessed to apparently have spread the furthest among all chemicals examined (Missiaen et al. 2010). Contamination detected in sediment samples ranged from 0.9 to 354 µg per kg of dry weight (Sanderson et al. 2010). Especially due to the very low water solubility of the original material, solid Adamsite can exist underwater in lumps consisting, at least below the surface, of an active agent (*cf.* Table 6).

Figure 49: A large 50 kg lump of Adamsite hauled up with the catch of a fishing vessel. Since it did not contain explosives, it could be safely disposed of at a land-based facility (Picture source: Maritime Surveillance Centre South on Bornholm).

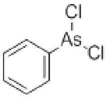
Adamsite has been reported among the material transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm. Additionally, Adamsite-containing chemical warfare materials have been found on GDR territory and have been recovered from the harbour basin of Wolgast in 1964 and dumped in the waters around Bornholm in 1962 and 1965, respectively. The presence of Adamsite has been proven by the detection of oxidation products in sediment and pore water samples in the wider area of the Bornholm dumpsite (Missiaen et al. 2010, Sanderson et al. 2010, Nord Stream AG 2011c). Lumps of Adamsite are also among the materials reported to have been trawled up by fishermen in the area east of Bornholm. Six incidents have been reported since 2000, each ranging between 20-80 kg of chemical agent (*cf.* Annex 7.2 - Table 7).

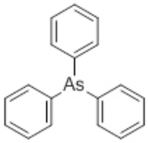
7.1.5 Clark I, Arsine Oil and Clark II

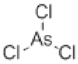




Diphenylchloroarsine (DA, Clark I) and diphenylcyanoarsine (DC, Clark II) are organoarsenic irritant compounds and are classified as sneezing or vomiting agents. Arsine oil is the designation of technical-grade Clark I and consisted of Clark I (35%), phenyldichloroarsine (50%, 'Pfiffikus'), triphenylarsine (5%) and trichloroarsine (5%) (Franke 1977).





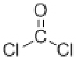


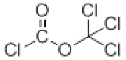
Especially Clark I and arsine oil have been used as additives in tactical mixtures of other chemical warfare agents (e.g., sulfur mustard), but munitions with Clark-filling are also known.

Both Clark I and Clark II hydrolyze in water into diphenylarsenious acid, which easily converts into bis(diphenylarsine)oxide (Haas et al. 1998b). Clark I generates hydrochloric acid and Clark II hydrogen cyanide in the process, both of which are toxic but are quickly neutralized and detoxified in seawater. While phenyldichloroarsine and trichloroarsine react in a similar fashion, the latter compound is an inorganic arsenic compound. Trichloroarsine gives rise to inorganic arsenic compounds upon hydrolysis, which are effectively indistinguishable from any naturally occurring arsenic compounds. Triphenylarsine on the other hand is not prone to hydrolysis but has a high tendency to adsorb to sediments and is considered as a signature compound for arsine oil (Missiaen et al. 2010). Due to its physicochemical properties, triphenylarsine was assessed to be among the most risky chemical warfare agent-related compounds with regard to the possible consumption of contaminated fish by humans (*cf.* Chapter 4.3.8) (Sanderson et al. 2009). Various compounds derived from Clark-type warfare materials have been found in sediment samples from the wider area of the Bornholm dumpsite (Missiaen et al. 2010, Sanderson et al. 2010, Nord Stream AG 2011c). Close to a wreck in the central dumpsite, the concentrations even reached 81 mg/kg of dry weight sediment for triphenylarsine. A signature compound for phenydichloroarsine was also detected in some pore water samples (Missiaen et al. 2010, Sanderson et al. 2010).

Clark-type and arsine oil warfare materials, summarized as arsenic-containing materials, have been reported among the material transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm (*cf.* Chapter 3.2.2 and Chapter 3.2.3). Crates filled with Clark I materials were recovered from the harbour basin of Wolgast in 1952/1953 and a bomb filled with Clark was found in 1954 on the beach of Sellin (Rügen) in the vicinity of the former transport routes. Clark-type warfare materials (sometimes referred to as 'sneezegas') are also among the materials reported to have been trawled up by fishermen in the area east of Bornholm (*cf.* Annex 7.2). As described above, Clark-type signature compounds have been detected in environmental samples taken from the wider area of the Bornholm dumpsite.

7.1.6 Phosgene and Diphosgene



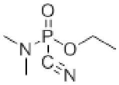


Phosgene is an activated form of carbonic acid and still today is an important building block for the chemical industry. It is considered by the OPCW as a toxic dual-use chemical, which may be a chemical weapon or a key ingredient for the generation of commercial products, depending on the purpose it is produced and stockpiled for (OPCW 2012). Phosgene is a colourless gas with a boiling point of 8.3 °C, classified as a lung agent and was filled into munitions in liquefied form. Diphosgene (‘Perstoff’) can be described as a ‘masked’ phosgene consisting of two molecules of phosgene bound together. Because of its higher mass, diphosgene is a liquid and can be handled more conveniently than the gaseous phosgene but acts like phosgene upon release. Tactical mixtures of phosgene and diphosgene, and also with chloropicrin, Clark, Adamsite or α-chloroacetophenone have been described (Kopecz & Thieme 1996).

Phosgene degrades extremely fast when it comes into contact with water (its half-life was calculated to be 0.4-1 s at 2 °C (Bizzigotti et al. 2009)). The alkaline pH of seawater accelerates the decomposition by neutralizing and buffering the released hydrochloric acid and carbonic acid. While a short-term impact will certainly occur on the immediate environment upon release (due to the violent release of hydrochloric acid), the break-down products are effectively non-toxic after dilution and neutralization.

Phosgene-type warfare materials have not been reported among the material transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm. Among other chemical warfare agents, phosgene-type materials discovered between 1960 and 1963 on GDR territory were transported and dumped in the waters around Bornholm. With respect to dumping activities, diphosgene might most likely have been included in the figures for phosgene. A single catch of phosgene-type materials was reported to have occurred in 1964 involving Polish fishermen (*cf.* Annex 7.2 - Table 8). In the 1994/1995 HELCOM CHEMU reports, the dumping of phosgene-type munitions has been reported as certain for the dumpsite south of the Little Belt (HELCOM 1994 & HELCOM 1995). While it cannot be excluded, this assessment was based on an assumption. Some bombs partially brought to the surface during investigations in the early 1970s had no contents. This was thought to originate from the corroding effects of hydrochloric acid released from phosgene upon contact with water (BSH 1993). Currently, no concrete chemical or historical evidence exists for the dumping of phosgene munitions south of the Little Belt.

7.1.7 Tabun



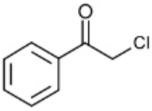
Tabun (ethyl dimethylphosphoramidocyanidate, also known as GA), is an organophosphate nerve agent. It is a liquid with a specific weight slightly higher than seawater (1.10 g/cm^3), even in oceanic salinity.

In German munitions, the payload filling was typically a mixture of 80% weapons-grade Tabun diluted with 20% chlorobenzene in order to conserve valuable active agent. A chemical analysis of three intact grenades recovered in 1971 from the dumpsite south of the Little Belt revealed a chlorobenzene content of 19-20%. The mixture in two of the grenades had decomposed due to aging to a remaining content of 0.08% and 0.6% Tabun, accompanied by overpressure from gaseous hydrogen cyanide generated in the process. A third grenade showed a small leakage at the filling hole, but still contained 72% of active agent. Tests conducted with guinea pigs directly contaminated with a drop of each payload filling and with mice exposed to it by air showed behavioural effects in all cases. The sample with high Tabun content had lethal results in both tests, while the mice exposed by air also died from the sample with 0.6% Tabun content (BSH 1993).

In the marine environment, Tabun hydrolyzes into phosphoric acid, dimethylamine and hydrogen cyanide. In seawater, at temperatures ranging from 7-15 °C, its half-life is approximately 5 - 8 hours. Thus, it poses a rather short-term threat to the marine environment, and only when it occurs in high concentrations (Bizzigotti et al. 2009).

Tabun-filled munitions are known to have been dumped in 1945 by German forces in the area south of the Little Belt due to investigations carried out in the late 1950s and early 1970s. The materials contained in two barges were recovered in 1959/1960, but apart from a few items recovered for research purposes the munitions originally dumped by item-by-item disposal were left in place. In addition, Tabun munitions were also found on GDR territory in the harbour basin of Wolgast in the early 1960s and recovered. This indicates that Tabun munitions have been moved under Soviet control from the harbour after WWII. It is unclear whether the transports were actually heading for the dumping areas in the Gotland Deep or the Bornholm Deep. No catches of nerve agent warfare materials are reported to have occurred by fishermen. Tabun has not been found in samples collected from the environment of the dumpsite east of Bornholm, possibly due to its instability in alkaline seawater (Missiaen et al. 2010).

7.1.8 α-Chloroacetophenone



α-Chloroacetophenone (also known as CN or CAP) is a solid riot control agent or tear gas. In German artillery shells, CAP was used either as a mixture with explosive and wax or as solid material surrounded by an explosive.

CAP is not easily soluble in water and hydrolyzes slowly, but produces non-toxic and non-persistent degradation products (Boguski et al. 2004, Missiaen et al. 2010). Especially due to the low water solubility of the original material, solid CAP can exist underwater in lumps consisting, at least below the surface, of an active agent. During the research carried out under the MERCW project, a sample of bottom sediment containing a considerable quantity of some agent was found in the central area of the Bornholm dumpsite originally designated for dumping. Analysis revealed it to be undissolved CAP (personal communication, V. Paka: Cruise report, PSh-77, SIO).

CAP has been reported among the materials (aircraft bombs and artillery shells) transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm. CAP-containing chemical warfare materials have also been recovered from the harbour basin of Wolgast in 1952/1953 and 1964 (wooden crates and artillery shells), with the latter subsequently being dumped in the waters around Bornholm. The teargas is also infrequently reported among the materials trawled up by fishermen in the area of the Bornholm dumpsite, either in form of solid lumps or in remnants of munitions. Since 1994, only four cases of catching CAP materials have been reported, amounting to altogether 2.5 kg of active agent (*cf.* Annex 7.2 - Table 6). The finding described in the paragraph above is the only known example of the detection of CAP-associated compounds in environmental samples from the dumpsites of chemical warfare materials in the Baltic Sea.

7.1.9 Hydrogen cyanide $H-C\equiv N$

Hydrogen cyanide can be released upon degradation of Tabun or Clark II. Immobilized on an adsorbent, with an added stabilizer and possibly a warning odorant, it was the active agent of the German pest control product ‘Zyklon B’. Apart from being used for purposes such as delousing, this product was used as a safe-to-handle suffocating killing agent in concentration camps’ gas chambers. Just like phosgene, the OPCW considers it as a potential dual-use toxic chemical (OPCW 2012).

Hydrogen cyanide dissolves in the alkaline seawater as cyanide. While effects on the immediate environment are possible upon release, it is easily and quickly degraded and dissipates in the marine environment.

Encasements of ‘Zyklon B’ have been reported among the material transported on behalf of the Soviet Military Administration from Wolgast to the designated dumping areas off Gotland and Bornholm (*cf.* Chapter 3.2.3). No catches of the material have been reported.

7.1.10 White phosphorus

White phosphorus is the most reactive modification of elemental phosphorus. Due to its property to spontaneously self-ignite when the solid is dry and in air, it has been used as an incendiary agent. Since white phosphorus often contains impurities giving it a yellowish appearance (‘yellow phosphorus’), it can be mistaken for amber. Apart from being highly toxic when taken up by humans, the injuries caused by the 1,300 °C hot flames and toxic smoke are severe. While not classified as a chemical warfare agent, the issue has nonetheless been brought to the attention of the OPCW by a number of concerned State Parties to the CWC (OPCW 2009).

The solubility of white phosphorus in water is very low (approximately 3 mg/L at 15 °C). In oxygen-deficient and saline seawater, white phosphorus was assessed to be indefinitely persistent (U.S. Army 1995).

Some coastal areas around the Baltic Sea have been contaminated with white phosphorus, stemming from incendiary munitions dropped during misrouted bombardments during WWII (e.g., on the island of Usedom) or due to munitions disposal during the Cold War period (e.g., the beach of Liepāja) (*cf.* Chapter 3.2.5). The contamination becomes apparent when incidents occur where people get severely injured after having pocketed nuggets of white phosphorus (mistaken for amber) found on beaches.

7.2 Lists of incidents

Table 7: Incidents reported since the establishment of the HELCOM reporting system in 1994. The position is given in decimal degrees (N / E, WGS84). The weight of the warfare agent payload (net weight) was estimated by visual inspection (Total: 5,410 kg). Disposal on land or the relocation to emergency disposal sites due to potential explosive hazards is indicated. CAP = α-chloroacetophenone.

Incident						Agent payload		Disposal	
No.	Year	ID	Position		Details	Type	m (kg)	Position	
106	2012	503-03/2012	55.26	15.36	lump	sulfur mustard	45	55.05	15.14
105	2011	5874-10/2011	55.17	15.67	lumps	sulfur mustard	3	55.04	14.63
104	2011	5761-09/2011	55.33	15.33	partially corroded KC250 bomb	sulfur mustard	60	55.08	15.24
103	2010	3301-04/2010	55.08	15.22	lumps	sulfur mustard	10	55.13	15.23
102	2010	2967-02/2010	unknown		lumps (from KC250 bomb)	sulfur mustard	40	55.08	15.24
101	2010	2930-01/2010	unknown		partially corroded Spray Can 37	sulfur mustard	15	55.04	14.63
100	2009	585-03/2009	55.17	15.62	six defect tips of teargas shells and small lumps	tear gas (CAP)	1.5	55.04	14.63
99	2008	14/2008	Nexø Havn		rear part of KC250 bomb. small residues of gas	sulfur mustard	0	on land	
98	2007	08/2007	55.24	15.32	lumps (from KC250 bomb)	sulfur mustard	55	55.08	15.24
97	2007	06/2007	55.52	14.87	lumps	sulfur mustard	3	on land	
96	2006	09/2006	54.85	15.2	lumps (from Spray Can 37)	sulfur mustard	6	55.08	15.24
95	2005	22/2005	55.82	15.92	lumps (from KC250 bomb)	sulfur mustard	40	55.08	15.24
94	2005	06/2005	55.26	15.15	lumps (from KC250 bomb)	sulfur mustard	35	55.08	15.24
93	2005	04/2005	55.1	15.2	partially corroded Spray Can 37	sulfur mustard	10	55.04	14.63
92	2005	01/2005	55.55	14.83	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
91	2004	08/2004	55.55	14.83	partially corroded Spray Can 37	sulfur mustard	10	55.04	14.64
90	2004	05/2004	55.28	15.44	lumps (from KC250 bomb)	sulfur mustard	30	55.12	14.64
89	2004	03/2004	55.07	15.13	lumps	Adamsite	20	on land	
88	2004	02/2004	55.05	15.34	corroded KC250 bomb (with opening charge)	sulfur mustard	100	55.08	15.24

87	2003	46/2003	54.93	15.09	lumps (from KC250 bomb)	sulfur mustard	100	55.08	15.24
86	2003	41/2003	54.97	15.33	lumps	Adam-site	80	on land	
85	2003	40/2003	55.03	15.67	lumps	sulfur mustard	1.5	on land	
84	2003	39/2003	55.03	15.67	lumps	tear gas (CAP)	0.25	on land	
83	2003	38/2003	55.38	16.2	corroded KC250 bomb (with opening charge)	sulfur mustard	100	55.08	15.24
82	2003	37/2003	55.33	16.43	lumps (from KC250 bomb)	sulfur mustard	10	55.08	15.24
81	2003	36/2003	55.45	15.92	lumps (from KC250 bomb)	sulfur mustard	70	55.04	14.64
80	2003	30/2003	55.43	15.48	lumps	sulfur mustard	3	on land	
79	2003	28/2003	54.73	15.45	lumps (from Spray Can 37)	sulfur mustard	10	55.08	15.24
78	2003	26/2003	55.07	15.72	lumps (from KC250 bomb)	sulfur mustard	90	55.08	15.24
77	2003	25/2003	54.95	15.73	two lumps (from KC250 bomb)	sulfur mustard	70	55.04	14.64
76	2003	24/2003	55.42	14.9	lumps	sulfur mustard	65	55.08	15.23
75	2003	23/2003	55.28	15.35	lumps	sulfur mustard	1.5	on land	
74	2003	21/2003	55.28	15.35	corroded KC250 bomb (with opening charge)	sulfur mustard	90	55.04	14.64
73	2003	20/2003	55.1	16.08	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
72	2003	19/2003	55.45	15.12	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24
71	2003	16/2003	55.33	15.38	lumps (from KC250 bomb)	sulfur mustard	50	55.08	15.24
70	2003	14/2003	55.02	15.4	lumps	sulfur mustard	30	55.07	14.64
69	2003	13/2003	55.4	15.78	lumps (from KC250 bomb)	sulfur mustard	35	55.04	14.64
68	2003	11/2003	55.4	15.1	lumps (from KC250 bomb)	sulfur mustard	100	55.08	15.23
67	2003	10/2003	55.4	16.24	lumps (from KC250 bomb. front part)	sulfur mustard	100	55.08	15.24
66	2003	08/2003	55.33	16.04	lumps (from KC250 bomb. front part)	sulfur mustard	60	55.04	14.64
65	2003	07/2003	55.42	15.08	lumps (from KC250 bomb. front part)	sulfur mustard	60	55.04	14.64
64	2003	03/2003	Nexø		4 tips of tear gas shells	tear gas (CAP)	0	on land	

63	2003	01/2003	55.22	15.13	lumps	Adam-site	25	on land	
62	2002	45/2002	55.04	15.27	lumps (from Spray Can 37)	sulfur mustard	10	55.08	15.24
61	2002	37/2002	55.15	15.24	lumps (from KC250 bomb)	sulfur mustard	70	55.08	15.24
60	2002	29/2002	55.07	15.24	corroded KC250 bomb (with opening charge)	sulfur mustard	130	55.07	15.33
59	2002	24/2002	55.04	15.24	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
58	2002	21/2002	55.13	15.28	partially corroded Spray Can 37	sulfur mustard	10	55.08	15.24
57	2002	20/2002	55.02	15.47	lumps (from KC250 bomb)	sulfur mustard	60	55.08	15.24
56	2002	14/2002	54.81	15.57	lumps (from KC250 bomb)	sulfur mustard	35	55.08	15.23
55	2002	13/2002	55.27	15.05	lumps	Adam-site	50	55.08	15.24
54	2002	12/2002	54.88	15.34	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24
53	2001	34/2001	54.92	14.96	lumps	Adam-site	25	on land	
52	2001	15/2001	55.03	15.27	lumps (from KC250 bomb)	sulfur mustard	15	55.08	15.24
51	2001	11/2001	55.25	17.01	lumps (from KC250 bomb)	sulfur mustard	3	55.04	14.64
50	2001	10/2001	54.98	15.26	lumps (from KC250 bomb)	sulfur mustard	0.15	on land	
49	2001	08/2001	54.86	15.01	lumps (from KC250 bomb)	sulfur mustard	190	55.08	15.24
48	2001	07/2001	55	15.33	lumps (from KC250 bomb)	sulfur mustard	60	55.04	14.64
47	2001	04/2001	Nexø Havn		bulk container	Clark I	1057	on land	
46	2001	03/2001	55.27	15.08	lumps (front part from KC250 bomb)	sulfur mustard	30	55.08	15.24
45	2001	02/2001	55.31	15.03	lumps (from KC250 bomb)	sulfur mustard	60	55.08	15.24
44	2001	01/2001	55.08	15.26	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24
43	2000	37/2000	55.93	14.88	lumps	Adam-site	30	55.08	15.24
42	2000	35/2000	55.31	14.83	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24
41	2000	25/1000	55.03	16.1	lumps (from KC250 bomb)	sulfur mustard	70	55.08	15.24
40	2000	23/2000	55.58	15.6	two lumps (from KC250 bomb)	sulfur mustard	115	55.08	15.24
39	2000	19/2000	54.93	15.33	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24

38	2000	12/2000	Nexø Havn		lumps	sulfur mustard	12	55.08	15.24
37	2000	11/2000	Nexø Havn		parts of KC250 bomb	sulfur mustard	0	55.08	15.24
36	2000	06/2000	55.29	15.35	lumps (from KC250 bomb)	sulfur mustard	30	55.08	15.24
35	2000	05/2000	Nexø Havn		rear part of KC250 bomb	sulfur mustard	0	on land	
34	2000	04/2000	55.47	14.87	lumps (from KC250 bomb)	sulfur mustard	40	55.08	15.24
33	2000	01/2000	55.02	15.77	lumps (from KC250 bomb)	sulfur mustard	125	55.08	15.24
32	1999	13/1999	55.03	15.38	corroded Spray Can 37 (with opening charge)	sulfur mustard	15	55.04	14.64
31	1999	08/1999	55.2	15.47	lumps (from KC250 bomb)	sulfur mustard	125	55.08	15.24
30	1999	01/1999	55.05	15.25	corroded KC250 bomb (with opening charge)	sulfur mustard	70	55.08	15.24
29	1998	25/1998	55.3	15.22	lumps	sulfur mustard	125	55.08	15.24
28	1998	15/1998	55.07	15.24	lumps (from KC250 bomb)	sulfur mustard	40	55.08	15.24
27	1998	11/1998	55.08	15.47	lumps (from KC250 bomb)	sulfur mustard	70	55.04	14.64
26	1998	05/1998	55.06	15.3	lumps	sulfur mustard	35	55.08	15.24
25	1998	03/1998	55.01	15.27	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
24	1997	13/1997	55.47	15.57	lumps	sulfur mustard	50	55.04	14.64
23	1997	12/1997	55.18	15.83	tip of tear gas shell	tear gas (CAP)	0.5	on land	
22	1997	11/1997	55.5	15.8	lumps (from KC250 bomb)	sulfur mustard	50	55.08	15.24
21	1997	09/1997	55.43	15.84	lumps (from KC250 bomb)	sulfur mustard	80	55.08	15.24
20	1997	08/1997	55.52	15.29	lumps (from KC250 bomb)	sulfur mustard	30	55.04	14.64
19	1997	07/1997	55.47	16.05	lumps (from KC250 bomb)	sulfur mustard	3	55.08	15.24
18	1997	06/1997	55.28	15.25	corroded Spray Can 37 (with opening charge)	sulfur mustard	8	55.07	15.24
17	1997	05/1997	55.26	15.68	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
16	1997	04/1997	55	15.33	corroded KC250 bomb (with opening charge)	sulfur mustard	80	55.08	15.24
15	1996	49/1996	55.08	15.48	lumps (from KC250 bomb)	sulfur mustard	15	55.07	15.23

14	1996	46/1996	55	15.3	lumps (from KC250 bomb)	sulfur mustard	50	55.07	15.22
13	1996	39/1996	55.08	15.28	lumps	Adam-site or Clark-type	50	on land	
12	1996	22/1996	55.05	15.77	lumps (from KC250 bomb)	sulfur mustard	20	55.08	15.24
11	1996	17/1996	55.05	15.36	lumps (from KC250 bomb)	sulfur mustard	30	55.07	15.23
10	1996	15/1996	55.8	15.53	corroded KC250 bomb (rear part with opening charge)	sulfur mustard	60	55.07	15.23
9	1995	34/1995	55.02	15.35	lumps (from KC250 bomb)	sulfur mustard	15	55.07	15.23
8	1995	07/1995	55.03	15.38	lumps (from KC250 bomb and part of acid mist container)	sulfur mustard	25	55.08	15.24
7	1995	04/1995	55.12	15.28	lumps (from KC250 bomb)	sulfur mustard	60	55.08	15.24
6	1995	03/1995	unknown		corroded KC250 bomb (front part. probably with opening charge)	sulfur mustard	30	55.08	15.23
5	1995	02/1995	55.04	15.41	lumps (from Spray Can 37. with opening charge)	sulfur mustard	7	55.08	15.24
4	1994	10/1994	Nexø Havn		partially corroded KC250 bomb (with opening charge)	sulfur mustard	100	55.08	15.24
3	1994	08/1994	55.5	16	partially corroded KC250 bomb (with opening charge)	sulfur mustard	100	55.04	14.64
2	1994	02/1994	55.35	15.43	lumps (parts of KC250 bomb)	sulfur mustard	unknown	dumped before arrival of team	
1	1994	01/1994	unknown		unknown - two persons injuried in the face and hands	sulfur mustard	unknown	dumped before arrival of team	

Table 8: Fishing and shoring incidents with chemical warfare materials in Poland. Compiled from Kasperek 1999 (1) and Szarejko & Namieśnik 2009 (2).

Nr.	Date (MM/YYYY)	Location	Fishing vessel	Incident	Active agent / object	Casualties
28	1983[1]	Central Baltic	WŁA	fishing	sulfur mustard	
27	06/1979	SW of Bornholm	WŁA-152	fishing	sulfur mustard	5 fishermen[1]; 1 fisherman[2]
26	05/1979[2]	SE of Bornholm[2]		fishing	sulfur mustard	
25	05/1979	Bornholm	KOŁ-78	fishing	sulfur mustard	3 fishermen
24	07/1977	Central Baltic		fishing	sulfur mustard [2]	
23	07/1977	SE of Bornholm	UST[2]	fishing	sulfur mustard [2]	
22	06/1977	E of Bornholm	DAR[2]	fishing	sulfur mustard [2]	
21	06/1977	Central Baltic	KOŁ-158	fishing	20 kg lump of sulfur mustard [1]	12 fishermen
20	06/1976	E of Bornholm [2]	DAR-51[2]	fishing	sulfur mustard [2]	3 fishermen
19	06/1976	Bornholm[2]	DAR-69[2]	fishing	sulfur mustard bomb[2]	3 fishermen
18	07/1974	SE of Bornholm[2]		fishing	sulfur mustard [2]	
17	06/1974	SE of Bornholm[2]		fishing	sulfur mustard [2]	
16	08/1971[2]	North of Hel[2]		fishing	sulfur mustard	
15	02/1971	North of Hel[2]		fishing	sulfur mustard [2]	
14	07/1969[1]	E of Bornholm Fishing area HJ-8	UST-3	fishing	sulfur mustard	crew
13	07/1967[1]	E of Bornholm Fishing area H-9	KOŁ-158	fishing	sulfur mustard	crew
12	05/1964[1]	Fishing area F-9	KOŁ-152	fishing	phosgene	crew
11	1963[1]	Fishing area J-7	UST-2	fishing	sulfur mustard	3 fishermen
10	05/1961[2]	N of Kołobrzeg	KOŁ-56	fishing	sulfur mustard	4 fishermen
9	05/1957[2]	Vicinity of Jarosławiec		shoring	barrel with arsine oil[3]	
8	07/1955	Darłówo		shoring	sulfur mustard barrel [2]	102 children (severely injured:4[1],7[2])
7	11/1954	Hel		shoring	sulfur mustard [2]	

6	09/1954	Jurata	shoring	sulfur mustard bomb[2]
5	06/1954	Gdańsk Bay	fishing	sulfur mustard bomb[2]
4	02/1953	Dziwnów	shoring	sulfur mustard bomb[2]
3	09/1952	Kołobrzeg	shoring	sulfur mustard bomb[2]
2	06/1952	E of Bornholm	fishing	sulfur mustard bomb[2]
1	06/1952	Dziwnów	shoring	sulfur mustard bomb[2]

Table 9: Incidents involving Danish fishermen 1968-1984, transcribed from SACSA 1991. The position is given in decimal degrees (N / E, potentially WGS84). The weight of the catch of seafood that had to be discarded because of the contamination is given. Irritant gas = Adamsite or Clark-types; tear gas = α-chloroacetophenone. Note: In the SACSA 1991 report, details were only provided of incidents that took place until April 1984. However, as the report mentions that approximately 50 incidents took place that year, Figure 41 indicates 50 incidents even thought this table only lists details of 32 incidents.

Nr.	Date (MM/YYYY)	Position		Fishing vessel	Active agent	Discarded catch (kg)
202	4/1984	55.33	15.33	RI 296	sulfur mustard	2,500
201	3/1984	55.05	15.58	R 40	sulfur mustard	1,250
200	3/1984	65 nm SE of Gotland		TN 177	sulfur mustard	1,025
199	3/1984	55.02	15.73	SG 77	sulfur mustard	3,750
198	3/1984	56.23	19.53	VA 36	sulfur mustard	20,000
197	3/1984	55.62	16.08	HG 158	sulfur mustard	46,350
196	3/1984	55.03	15.43	R 146	sulfur mustard	500
195	3/1984	12 nm off Christiansø		H 260	sulfur mustard	1,250
194	3/1984	55.87	18.73	L 332	sulfur mustard	6,250
193	3/1984	55.05	15.33	R 305	sulfur mustard	1,500
192	2/1984	55.20	15.57	R 40	sulfur mustard	1,250
191	2/1984	55.42	16.03	HG 135	sulfur mustard	5,250
190	2/1984	55.47	15.18	R 283	sulfur mustard	1,000
189	2/1984	55.05	15.42	SE 138	irritant gas	1,125
188	2/1984	55.17	15.37	R 237	irritant gas	1,500
187	2/1984	55.18	15.48	R 270	irritant gas	1,125
186	2/1984	54.98	15.52	L 322	sulfur mustard	2,100

185	2/1984	55.00	15.50	R 349	sulfur mustard	800
184	2/1984	55.12	15.03	R 353	irritant gas	1,875
183	1/1984	55.12	15.32	R 229	irritant gas	2,500
182	1984	54.98	15.57	R 247	sulfur mustard	1,000
181	1984	55.18	15.87	T 100	irritant gas	3,250
180	1984	55.23	15.77	R 283	sulfur mustard	1,875
179	1984	55.27	15.32	R 330	sulfur mustard	2,000
178	1984	55.07	15.65	R 342	sulfur mustard	1,000
177	1984	55.20	15.40	R 266	sulfur mustard	900
176	1984	55.20	15.33	R 225	sulfur mustard	2,000
175	1984	55.50	16.17	SE 205	sulfur mustard	1,250
174	1984	55.03	15.72	T 226	sulfur mustard	1,200
173	1984	A 42.5 Grøn B 20.0 Rød		R 155	irritant gas	950
172	1984	55.08	15.45	SE 235	sulfur mustard	1,250
171	1984	55.33	15.40	SE 148	tear gas	1,250
170	6/1983	J 44 Grøn B 18 Rød		R 73	sulfur mustard	450
169	6/1983	55.23	15.37	R 73	irritant gas	500
168	5/1983	A 33 Grøn C 3 Rød		R 322	sulfur mustard	625
167	5/1983	55.32	16.07	R 106	sulfur mustard	6,750
166	4/1983	55.20	15.38	SE 148	tear gas	1,450
165	4/1983	I 42.25 Grøn D 4.67 Rød		R 241	sulfur mustard	5,925
164	4/1983	55.22	16.03	R 91	sulfur mustard	6,250
163	4/1983	7.5 nm ESE of Nexø		R 187	sulfur mustard	2,500
162	3/1983	54.95	15.50	R 323	sulfur mustard	1,500
161	3/1983	J 17.5 Grøn B 39 Rød		NF 6	irritant gas	1,500
160	3/1983	J 34 Grøn B 12 Rød		R 132	sulfur mustard	5,900
159	2/1983	I 42 Grøn D 2 Rød		R 91	sulfur mustard	2,250
158	2/1983	H 39 Grøn C 9 Rød		FN 393	sulfur mustard	4,000
157	2/1983	I 39 Grøn B 15 Rød		T 120	sulfur mustard	7,600
156	1/1983	12 nm SE of Svaneke		R 249	sulfur mustard	625
155	1/1983	A 36 Grøn B 32 Rød		R 327	sulfur mustard	1,350
154	1/1983	55.22	15.22	R 273	sulfur mustard	1,125
153	1/1983	55.13	15.22	R 211	sulfur mustard	875
152	1/1983	55.17	15.27	T 424	irritant gas	350
151	1983	55.87	19.05	L 529	sulfur mustard	3,100
150	8/1982	55.20	15.37	R 149	sulfur mustard	150
149	7/1982	J 43.5 Grøn B 18 Rød		R 279	sulfur mustard	400
148	7/1982	12 nm ENE of Nexø		SE 47	sulfur mustard	600
147	5/1982	55.07	15.62	R 165	sulfur mustard	700

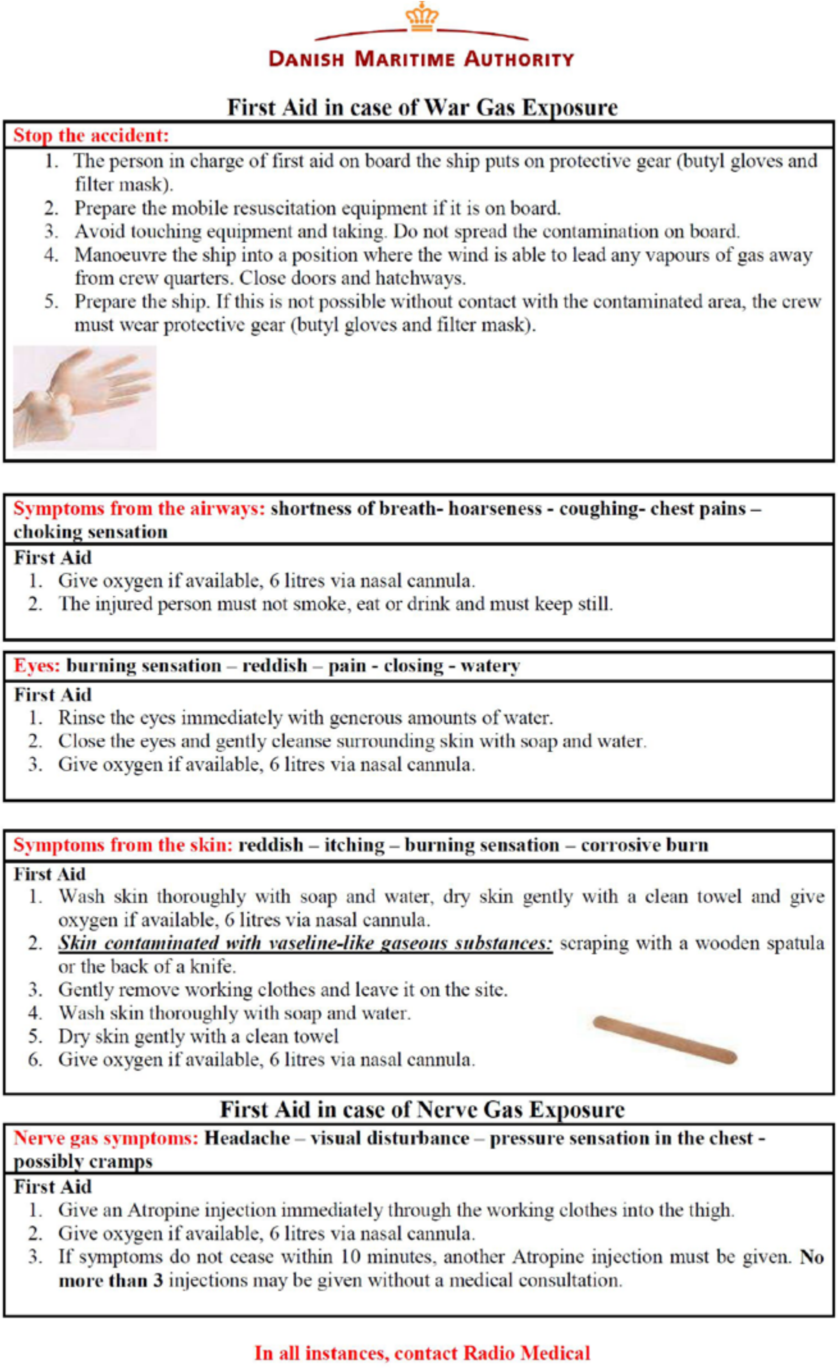
146	4/1982	54.98	15.47	R 110	sulfur mustard	875
145	3/1982	A 36 Grøn C 0 Rød		SE 74	irritant gas	750
144	2/1982	10 nm ENE of Nexø		R 247	sulfur mustard	2,500
143	2/1982	14 nm E to south of Nexø		R 15	irritant gas	1,750
142	2/1982	14sm ENE of Nexø		R 185	sulfur mustard	1,500
141	2/1982	14 nm E of Nexø		R 110	sulfur mustard	1,800
140	2/1982	A 37 Grøn B 15 Rød		R 279	irritant gas	2,500
139	2/1982	4 nm N of Svaneke		R 165	sulfur mustard	800
138	1/1982	3.5 nm E of lighthouse Svaneke		SE 144	irritant gas	625
137	1/1982	A 38.7 Grøn B 1.7 Rød		R 183	sulfur mustard	1,125
136	1982	54.92	15.03	SE 22	sulfur mustard	500
135	1982	1.5 nm SE of Christiansø		R 165	sulfur mustard	1,000
134	12/1981	5 nm NE of lighthouse Hammeren		R 100	sulfur mustard	1,250
133	9/1981	55.13	15.42	R 91	sulfur mustard	2,250
132	7/1981	1.5-8 nm SE of Christiansø		R 72	sulfur mustard	575
131	5/1981	55.28	15.12	SE 144	sulfur mustard	1,000
130	5/1981	12 nm E of lighthouse Svaneke		SE 198	sulfur mustard	875
129	5/1981	6 nm E of lighthouse Svaneke		SE 198	irritant gas	250
128	5/1981	10 nm NE of lighthouse Sveneke		R 73	sulfur mustard	1,800
127	3/1981	55.18	15.42	R 103	sulfur mustard	1,250
126	3/1981	14 nm E to south of Nexø		SE 22	sulfur mustard	1,800
125	3/1981	6 nm ENE of Nexø		R 135	sulfur mustard	900
124	3/1981	55.17	15.53	R 188	sulfur mustard	2,500
123	2/1981	55.08	15.25	R 110	irritant gas	1,500
122	2/1981	54.90	15.35	SE 77	sulfur mustard	2,000
121	2/1981	55.12	15.50	R 103	sulfur mustard	875
120	2/1981	55.03	15.35	SE 61	sulfur mustard	625
119	1981	13.5 nm E of lighthouse Sveneke		SE 113	sulfur mustard	375
118	1981	54.95	15.43	R 135	sulfur mustard	3,000
117	12/1980	55.10	15.28	R 284	irritant gas	2,800
116	12/1980	55.18	15.43	R 232	sulfur mustard	2,000
115	12/1980	55.08	15.32	R 239	irritant gas	1,125
114	9/1980	3 nm SE of Christinasø		R 265	sulfur mustard	500
113	9/1980	55.47	14.72	H 260	sulfur mustard	300
112	8/1980	55.25	15.42	R 237	sulfur mustard	875
111	7/1980	55.30	15.40	SE 198	sulfur mustard	1,250
110	6/1980	55.20	16.00	SE 153	sulfur mustard	3,750
109	6/1980	55.12	15.67	SE 132	sulfur mustard	1,500

108	4/1980	55.10	15.70	R 56	sulfur mustard	875
107	3/1980	55.37	16.42	ND 58	sulfur mustard	2,250
106	3/1980	55.03	15.33	R 232	sulfur mustard	2,750
105	3/1980	55.07	15.58	R 279	sulfur mustard	7,500
104	3/1980	55.10	15.57	SE 132	sulfur mustard	625
103	3/1980	55.22	15.32	H 135	sulfur mustard	4,000
102	2/1980	55.35	15.38	R 211	sulfur mustard	1,500
101	2/1980	55.27	15.50	Se 13	sulfur mustard	1,400
100	2/1980	55.30	15.42	NF 6	sulfur mustard	1,750
99	1/1980	55.07	15.62	R 240	sulfur mustard	1,250
98	1980	55.23	15.30	R 56	sulfur mustard	375
97	1980	55.00	15.67	R 249	sulfur mustard	2,500
96	1980	55.37	15.33	R 193	sulfur mustard	2,375
95	11/1979	A 39.5 Grøn B 15 Rød		R 247	sulfur mustard	900
94	11/1979	J 32 Grøn C 20 Rød		R 249	sulfur mustard	3,500
93	10/1979	55.35	14.83	R 56	sulfur mustard	450
92	9/1979	10 nm E to north of Listed		R 165	irritant gas	675
91	6/1979	8 nm E of Nexø		R 40	sulfur mustard	125
90	6/1979	12 nm NE of Svaneke		R 165	sulfur mustard	1,250
89	3/1979	H 31.6 Grøn C 12 Rød		R 223	sulfur mustard	3,500
88	3/1979	55.35	15.37	S 405	sulfur mustard	10,000
87	3/1979	12 nm ENE of Listed		R 56	sulfur mustard	875
86	5/1978	55.87	18.50	R 62	sulfur mustard	1,875
85	5/1978	55.15	15.67	O 65	irritant gas	1,750
84	5/1978	55.02	15.68	Se 22	sulfur mustard	1,600
83	4/1978	8 nm E to south of Nexø		SE 22	sulfur mustard	1,800
82	3/1978	16 nm E to south of Nexø		SE 22	irritant gas	225
81	3/1978	55.90	18.75	R 193	sulfur mustard	2,250
80	3/1978	12 nm NE to north of Nexø		R 263	sulfur mustard	1,375
79	2/1978	15 nm E to south of Nexø		SE 29	sulfur mustard	750
78	2/1978	15 nm ESE of of Aarsdale		SE 3	sulfur mustard	700
77	1/1978	20 nm E to south auf Nexø		R 232	sulfur mustard	550
76	1/1978	55.13	15.50	R 193	sulfur mustard	1,000
75	1978	5 nm ENE of Nexø		R 176	sulfur mustard	500
74	7/1977	12 nm E, 0.5 N of Nexø		SE 189	sulfur mustard	475
73	6/1977	10 nm NE of Svaneke		R 56	sulfur mustard	625
72	6/1977	H 44 Grøn C18 Rød		R 112	sulfur mustard	1,750
71	5/1977	H 38 Grøn C9 Rød		R 112	sulfur mustard	1,625
70	5/1977	H 39 Grøn C9 Rød		R 193	sulfur mustard	1,875

69	4/1977	28 nm SE of Nexø	M 48	sulfur mustard	400
68	4/1977	H 36 Grøn C 5 Rød	SE 104	sulfur mustard	600
67	4/1977	8 nm NE of Christiansø	S 115	sulfur mustard	2,200
66	4/1977	26 nm E to south of Nexø	SE 29	sulfur mustard	1,500
65	4/1977	21 nm E to south of Nexø	R 189	sulfur mustard	300
64	4/1977	G 46.7 Grøn C 16.5 Rød	S 29	sulfur mustard	4,400
63	3/1977	27 nm NE to N of Nexø	SE 189	tear gas	500
62	3/1977	11 nm E of Nexø	R 135	sulfur mustard	2,000
61	3/1977	H 30 Grøn C9 Rød	R 193	sulfur mustard	2,000
60	3/1977	H 36 Grøn C 16 Rød	FN 24	sulfur mustard	1,600
59	3/1977	14 nm NE to N of Svaneke	SE 183	sulfur mustard	700
58	3/1977	17 nm NNE of Nexø	NF 108	sulfur mustard	820
57	2/1977	18 nm E to south of Nexø	R 176	sulfur mustard	1,600
56	2/1977	16 nm E 0.5 S of Nexø	SE 22	sulfur mustard	800
55	1977	12 nm NE of Svaneke	R 165	sulfur mustard	1,250
54	11/1976	4 nm N of Listed	R 165	sulfur mustard	270
53	9/1976	35 nm NE 0.5 N of Nexø	SE 227	sulfur mustard	1,000
52	9/1976	3 nm SE of Christinasø	R 165	sulfur mustard	450
51	9/1976	27 nm NNE of Nexø	R 97	sulfur mustard	1,375
50	8/1976	27 mm N to E 0.5 of Nexø	KR 123	sulfur mustard	1,250
49	8/1976	4 nm N of Christiansø	R 165	sulfur mustard	625
48	8/1976	22 nm N of Nexø	R 97	sulfur mustard	250
47	7/1976	15 nm NE of Nexø	R 97	sulfur mustard	1,500
46	7/1976	5 nm N of Christiansø	NF 80	sulfur mustard	1,000
45	7/1976	38 nm NE of Nexø	SE 80	sulfur mustard	1,750
44	7/1976	22 nm NE of Christiansø	R 106	sulfur mustard	3,750
43	7/1976	I 37 Grøn B 22.5 Rød	R 50	sulfur mustard	400
42	7/1976	17 nm NNE of Nexø	R 214	sulfur mustard	1,625
41	7/1976	20 nm NE of Christiansø	R 106	sulfur mustard	2,250
40	7/1976	4 nm NNE of Chrisitansø	R 106	sulfur mustard	1,500
39	6/1976	4 nm N of Christiansø	SE 198	sulfur mustard	875
38	6/1976	19 nm NNE of Aarsdale	SE 3	sulfur mustard	1,000
37	6/1976	36 nm NE of Nexø	M 83	sulfur mustard	1,000
36	6/1976	37 nm NE of Nexø	KR 142	sulfur mustard	1,250
35	6/1976	14 nm NNE of Aarsdale	SE 170	sulfur mustard	1,100
34	6/1976	15 nm NE of Christiansø	R 106	sulfur mustard	2,750
33	6/1976	35 nm NE of Svaneke	SE 144	sulfur mustard	1,750
32	6/1976	37 nm E to N of Nexø	R 156	sulfur mustard	1,500
31	6/1976	H 45 Grøn C 1 Rød	R 2	sulfur mustard	1,000

30	5/1976	33 nm NE to N of Nexø	SE 66	sulfur mustard	1,750
29	5/1976	B 20.5 I 36.5	R 137	sulfur mustard	1,000
28	5/1976	35 nm E to north of Nexø	R 221	sulfur mustard	850
27	5/1976	32 nm NE to N of Nexø	ND 34	sulfur mustard	625
26	4/1976	28 nm E 1/2 N of Nexø	SE 22	sulfur mustard	600
25	4/1976	I 42 Grøn B 8 Rød	KA 25	sulfur mustard	400
24	1976	29 nm E to north of Nexø	NF 6	sulfur mustard	4,890
23	1976	55.33 16.00	R 214	mustard gas	1,500
22	4/1975	12 nm NE of Svaneke	SE 3	sulfur mustard	800
21	3/1975	7 nm SE of Christiansø	SE 168	sulfur mustard	360
20	2/1975	10 nm NE of Christiansø	R 60	sulfur mustard	8,600
19	1/1975	11 nm NE of Svaneke	R 16	sulfur mustard	625
18	1/1975	16 nm E to south of Nexø	R 135	sulfur mustard	360
17	1/1975	7 nm SE of Christiansø	SE 118	sulfur mustard	800
16	1/1975	5 nm ESE of Aarsdale	SE 204	sulfur mustard	625
15	1975	5 nm NE of Nexø	SE 138	sulfur mustard	625
14	3/1974	8 nm E to south of Nexø	SE 221	irritant gas	500
13	7/1973	12 nm E of Nexø	SE 81	sulfur mustard	320
12	6/1973	14 nm SSE of Nexø	SE 19	sulfur mustard	250
11	3/1973	15 nm NE of Christiansø	R 69	sulfur mustard	2,500
10	1/1973	24 nm E to south of Nexø	SE 75	sulfur mustard	600
9	6/1972	7 nm North of Christiansø	R 11	sulfur mustard	500
8	4/1972	42 nm E to north of Nexø	SE 156	sulfur mustard	450
7	4/1972	15 nm E 0.5 north of Nexø	AS 56	sulfur mustard	1,500
6	4/1972	9 nm SE to south of Nexø	SE 1	sulfur mustard	290
5	3/1972	42 nm E to north of Nexø	SE 83	sulfur mustard	4,200
4	8/1970	4 nm S 0.5 E of lighthouse Dueodde	SE 76	sulfur mustard	1,500
3	8/1970	17 nm E to south of Nexø	SE 119	sulfur mustard	160
2	5/1969	16 nm NE to E of Christiansø	SE 171	sulfur mustard	1,900
1	4/1968	14 nm E of Nexø	R 93	sulfur mustard	2,400

7.3 First aid guidelines



DANISH MARITIME AUTHORITY

First Aid in case of War Gas Exposure

Stop the accident:

1. The person in charge of first aid on board the ship puts on protective gear (butyl gloves and filter mask).
2. Prepare the mobile resuscitation equipment if it is on board.
3. Avoid touching equipment and taking. Do not spread the contamination on board.
4. Manoeuvre the ship into a position where the wind is able to lead any vapours of gas away from crew quarters. Close doors and hatchways.
5. Prepare the ship. If this is not possible without contact with the contaminated area, the crew must wear protective gear (butyl gloves and filter mask).

Symptoms from the airways: shortness of breath- hoarseness - coughing- chest pains – choking sensation

First Aid

1. Give oxygen if available, 6 litres via nasal cannula.
2. The injured person must not smoke, eat or drink and must keep still.

Eyes: burning sensation – reddish – pain - closing - watery

First Aid

1. Rinse the eyes immediately with generous amounts of water.
2. Close the eyes and gently cleanse surrounding skin with soap and water.
3. Give oxygen if available, 6 litres via nasal cannula.

Symptoms from the skin: reddish – itching – burning sensation – corrosive burn

First Aid

1. Wash skin thoroughly with soap and water, dry skin gently with a clean towel and give oxygen if available, 6 litres via nasal cannula.
2. ***Skin contaminated with vaseline-like gaseous substances:*** scraping with a wooden spatula or the back of a knife.
3. Gently remove working clothes and leave it on the site.
4. Wash skin thoroughly with soap and water.
5. Dry skin gently with a clean towel
6. Give oxygen if available, 6 litres via nasal cannula.

First Aid in case of Nerve Gas Exposure

Nerve gas symptoms: Headache – visual disturbance – pressure sensation in the chest - possibly cramps

First Aid

1. Give an Atropine injection immediately through the working clothes into the thigh.
2. Give oxygen if available, 6 litres via nasal cannula.
3. If symptoms do not cease within 10 minutes, another Atropine injection must be given. **No more than 3** injections may be given without a medical consultation.

In all instances, contact Radio Medical

Figure 50: Danish first aid instructions in case of exposure to chemical warfare agents.

7.4 Factors for hazard and risk assessments

The possible factors given here would need to be considered within a risk assessment as described in Chapter 4 and are provided as an example without claiming to be complete.

Warfare materials - types, conditions and on-site distribution

- form (e.g., bomb, shell, container) - fuzed / unfuzed (relates to origin and mode of disposal) - integrity of containment (damage / corrosion / lump formation) and functionality (detonation / payload effects)
- payload (conventional / chemical) / bio-toxicity of contained compound mixtures (e.g., explosives, main chemical warfare agents, by-products, solvents) and degradation products
- type of explosives / shock-sensitivity of explosives / danger of spontaneous detonation (due to ageing of constituents)
- distribution of warfare materials (especially related to mode of former disposal)
- degree of (possible) contamination with chemical warfare agents or explosive compounds and their degradation products

Influencing on-site conditions

- type of sediment
- hydrodynamic effects
- temperature and presence of oxygen
- indication on sea charts (e.g., foul grounds, areas for deposition of gravel and sand) and prevention arrangements (e.g., warnings regarding anchoring and fishing)

Intended on-site operations

- diving or fishing
- anchoring
- construction in or on seabed
- (dredging / commercial extraction of sand and gravel from the seabed) - relocation (dumping) of sediments

Figure 51: Possible factors for hazard and risk assessments.

When an encounter of chemical munitions (*cf.* Table 5), chemical warfare agents or their hazardous degradation products in the marine environment of the Baltic Sea is possible or even probable, it is recommended that a detailed list should be elaborated for the specific planned operation, the circumstances and objectives which a risk assessment should cover.

Of special importance, and with numerous risk-increasing (or decreasing) effects on risk, are the formerly employed modes of disposal: item-by-item overboard disposal or scuttling of ships (*cf.* Table 10).

Table 10: The factor 'former mode of disposal' and its effects on risk.

Mode of disposal	Effects (risk-increasing (+) or risk-decreasing (-))
Item-by-item overboard disposal (in designated target area or en route)	(+) larger size of contaminated area
	(-) smaller individual pollution capacity of sources and potential influx load per area
	(+/-) uncertain locations, difficult to find and to recover, but manageable due to size of objects
	(+/-) more diverse conditions, therefore larger diversity of environmentally influenced aging and corrosion; large uncertainty with regard to condition of objects; rather non-concerted release over a longer period
	(-) with regard to space and time, lower maximum concentrations reachable, so larger potential of environmental self-regulating forces to be effective
	(-) smaller likelihood of sympathetic release due to single events, e.g. (self-) detonation of a single munitions object
	(+) more difficult to mark on maps due to uncertainty (especially for en route dumping)
	(+) greater likelihood of encountering objects due to uncertain locations (+) greater likelihood of spreading and unintentional recovery, e.g. by fishing, due to size and uncertain distribution of objects
Scuttling of vessels (most likely in designated target area)	(-) large object equals large point source for pollution; higher concentration of chemical warfare agents inside the remaining hull of the ship.
	(-) hull of ship (if not broken apart during scuttling) forms additional protective layer against environmental and external influences
	(+) containment and / or removal in case of required action difficult due to size, but manageable with regard to distribution
	(-) likelihood of comparable environmental conditions for the cargo, therefore lower diversity of environmentally influenced aging and corrosion, therefore uncertainty with regard to condition of objects smaller
	(+) greater likelihood of concerted release in a shorter time frame
	(+/-) smaller likelihood to discover the whole magnitude of environmental pollution in monitoring programs due to potential inaccessibility of cargo bays, but larger pollution due to non-scattered source
	(+) with regard to space and time, high maximum concentrations reachable, small potential of environmental self-regulating forces to be effective
	(+) greater likelihood of sympathetic release due to single events, e.g. (self-) detonation of a single munitions object
	(-) smaller uncertainty of location of wrecks
	(-) less difficult to mark on maps
	(-) smaller likelihood of encountering wrecks
	(-) smaller likelihood of unintentional recovery, due to size of and containment of cargo in wrecks

7.5 List of contributing authors and institutions

The report has been compiled based on national reports of the state countries, with the special contributions by experts of the *ad hoc* Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI).

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Ministry of the Environment	Kirsi Kentta
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