Chemical munition dump sites in coastal environments : a border-transgressing problem

TINE MISSIAEN & JEAN-PIERRE HENRIET

Renard Centre of Marine Geology, University of Gent, Krijgslaan 281 - S8, B-9000 Gent, Belgium

Introduction

The problem posed by sea-dumped chemical weapons deserves considerable international attention: the amount of these weapons dumped in the North European seas since the end of World War I runs into hundreds of thousand of tons at least. The toxic warfare, often dumped in relatively shallow waters and areas of active fishing, not only represents a serious threat to the marine environment but also to the often densely populated European coasts. Because many dumping operations were carried out secretly, it is not always clear who can be held responsible. Some dump sites are located in international waters (and thus beyond any particular nation's responsibility), although more often dumping operations were carried out in territorial waters near the borders of neighbouring states.

Highly toxic material has time and again showed up, for instance when retrieved in fishing nets or washed ashore on beaches, attracting local media coverage only. Nevertheless, this issue has not always been given adequate and comprehensive scientific attention. In fact, the problem has been neglected for a long time at the international level, and some countries which conducted dumping operations have only recently made official data available.

There were a number of reasons for the decades of delay in addressing this problem. For one thing the issue is politically sensitive because it raises the problem of accountability, and the government bodies of both the states that carried out the operations and those bordering the dumping areas were reluctant to tackle this sensitive problem (especially during the Cold War). These political obstacles have mostly been removed now. Another factor is the complexity of this matter, which requires comprehensive and profound expertise and therefore involves a huge commitment of financial and technological resources.

In recent years, however, sea-dumped chemical weapons have been the subject of growing concern in a number of international fora and workshops. Although the full extent of the dumping operations still remains unclear (due a lack of documentation and loss or destruction of records), a large number of dump sites have been documented.

Historical background

Chemical weapons (CW) were first used on a large scale in the battle of Ypres in April 1915. During the entire First World War a wide range of toxic warfare agents was produced

(at least 40 different compounds) and employed on the battlefields. An estimated 1.45 billion shells were fired during the war; about 66 million of these contained toxic agents.

Outrage at the effects of chemical warfare led to the signing in 1925 of the Geneva Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and Bacteriological Methods of Warfare. Strangely enough the treaty did not forbid the development, production and possession of these weapons. A large number of nations signed the treaty, but also expressed that they should maintain the right to retaliate any chemical attack on their territory with the same means, as well as the right to use chemical weapons against non-signatories of the protocol.

The invention of organophosphor compounds (a.o. Sarin, Tabun and Soman) in the 1930's and 1940's gave a new dimension to chemical warfare. During World War II no chemical weapons were employed, although large stocks were produced by Germany, the US, Japan, the Soviet Union and the UK. In 1945 the allied countries installed an inspection committee charged with the detection, dismantling and recovery of the - mainly German - CW stocks. At that time dumping at sea was considered the best and most practical solution to get rid of these old CW stocks, thereby completely ignoring the consequences for the environment.

Also after World War II the production of CW continued, and on several occasions chemical weapons were deployed at war (a.o. in Vietnam, Yemen, Kurdistan, Iraq, Iran). For decades dumping at sea remained a widely used method to reduce old or obsolete stocks. With the growing environmental protest in the 1970's the number of dumping operations at sea gradually declined, and in many countries it is nowadays forbidden.

A first important step in dealing with the problem of unconventional weapons was made in 1972 with the opening for signature of the "Biological and Toxic Weapons Convention" (BTWC). The treaty forbids the development, production and storage of bacteriological, biological and toxin weapons. The BTWC entered into force in 1975.

During the 1980's further steps were taken towards a convention banning chemical weapons. Many years of hard effort finally led to the signing of the "Chemical Weapons Convention" (CWC) in 1993. The CWC prohibits the development, production, stockpiling and use of chemical war material for military purposes and calls for the destruction of the present stocks. The parties to the CWC need to clarify the status of sea-dumped chemical munitions under the convention. The CWC, however, provides no incentives to recover chemical weapons that were sea-dumped before 1985. If CW are recovered their status under the CWC may be uncertain as declarations of such recovery are voluntary and the treaty contains no explicit destruction requirements for such recovered munitions.

As a result of the growing environmental awareness the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo Convention) was signed in 1972. It entered into force in 1974. In that same year the Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention) was signed, entering into force in 1978. In 1992 both conventions merged into the new Oslo-Paris Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR Convention), which entered into force in 1998.

In 1974 the first Convention for the Protection of the Marine Environment of the Baltic was signed (Helsinki Convention). In 1992, a new Convention was signed by all the

countries bordering on the Baltic Sea and by the European Economic Community. The new 1992 Convention entered into force in January 2000. The governing body of the Convention is the Helsinki Commission or HELCOM.

It is generally accepted that CW cannot be openly dumped at sea today. The CWC explicitly forbids the dumping of CW in any body of water for its state parties (Verification Annex, Part IV(A), § 13). The OSPAR and HELCOM Conventions forbid the dumping of toxic waste at sea; however in these treaties no explicit reference is made to war material. Still, there is no other way than considering a chemical warfare agent as a toxic substance: this characteristic is at the heart of the definition of chemical weapons.

Major CW dump sites

Although sea-dumping of CW started already after World War I, the first intensive dumping efforts came right after World War II. Between 1945 and 1948 some 300,000 tons (gross weight) of CW were recovered on German territory (HELCOM CHEMU 1994; Anon. 1993). By far the largest part of these weapons (according to Stock (1996) as much as 85%) were dumped in the Baltic Sea and Skagerrak Strait on the orders of the British, Russian and American occupation authorities. Up to now over 80 conventional and chemical munition dump sites have been identified in the North Sea and Northeast Atlantic, excluding the Baltic Sea (OSPAR 2002). However this list is probably not complete - according to Paetzel (this volume) at least 5 known Norwegian dump sites, located in the Skagerrak and in fjords, are not included.

At least 170,000 tons of CW were dumped in the Skagerrak (HELCOM CHEMU 1994; Anon. 1993; Stock 1996, Duursma 1999; Laurin 1997). The main dump site is located in the Norwegian Trench, south of Arendal, where 9 ships (containing roughly 30,000 tons of CW) were sunk by the American authorities (operation "Davey Jones Locker"), and more than 30 ships (containing over 125,000 tons of CW) were sunk by the British authorities (Stock 1996; Laurin 1997; Frondorf 1996; Fonnum 1993). At least 9 ships (some estimations mention 16 ships) were scuttled by the British authorities off the Swedish coast, 25 miles west of Måseskär (Laurin 1997; Granbom 1996). The total content of CW is unknown, but at least 2 ships loaded with 20,000 tons of CW were sunk here (Granbom 1996).

In the Baltic Sea at least 50,000 tons of CW were dumped by the Russian, British and German authorities. Most of the munition was thrown over the side of the ship, in some cases entire ships were sunk. The largest dump site is located off Bornholm, where over 40,000 tons of CW were dumped. Other dump sites include the Little Belt, where 2 ships loaded with 69,000 Tabun shells and 5000 tons of CW were dumped, and the Gotland Basin, 70 miles west of Liepaja, where 2000-5000 tons of CW were dumped (HELCOM CHEMU 1994; Anon. 1993; Duursma 1999; Laurin 1997). There are also indications that the munition was partially thrown over board during transport to the Baltic dump sites, but the exact amount is not known (Laurin 1997; Andrulewicz 1996).

Large quantities of CW were also dumped in the North Sea after World War II. Off the Norwegian west coast the United States dumped two vessels containing 4500 tons of CW (Laurin 1997; Frondorf 1996). Several ships were also scuttled near the island of Helgoland. Off the German coast chemical and conventional ammunition was dumped on a

large scale by the German authorities. The total amount of dumped warfare is estimated to roughly 1.5 million tons. At this moment 16 different dump sites are known, from the Wadden Sea to the North Friesian islands (Rapsch & Fisher 2000). Many of these dump sites are located in very shallow water, in some cases even surfacing at low tide. At least 12 ships loaded with CW were sunk near the Doggerbank (Rapsch & Fisher 2000).

Shortly after World War II the UK conducted extensive dumping operations in the Atlantic Ocean to dispose of its WW2 stockpile of CW. During the operation codenamed "Sandcastle" huge quantities of CW (including 120,000 tons of mustard gas munition and 17,000 tons of Tabun munition) were dumped in deep water off the Hebrides, Land's End and NW Ireland (Anon. 2001). In Beaufort's Dyke, a 200-300 m deep and 3.5 km wide trench between Scotland and Northern Ireland, over 1 million tons (according to some sources up to 2 million tons) of chemical and conventional war material has been dumped since 1945, possibly from as early as 1920; the last dumping operation probably took place in 1976 (Anon. 2001; SOAEFD 1996).

Since World War II large amounts of CW have been dumped by the Soviet authorities in the arctic seas. On this subject there is hardly any official information. According to an American study (MEDEA 1997) a maximum of approximately 115,000 tons of mustard gas and Lewisite were dumped into the White Sea, the Barents Sea and Kara Sea. In addition, a maximum of 32,000 tons of Tabun and Sarin was estimated to have been dumped in these seas. In total 5 potential dump sites have been identified in the area (MEDEA 1997).

No official data are available about possible CW dump sites off the French coast. Unofficial sources report the clearing of stocks of WW1 ammunition, a.o. at the mouth of the Somme river, where the war material was dumped in big pits at low tide and brought to explode at high tide. According to Laurin (1997) at least 3 vessels loaded with CW were sunk in the Bay of Biscay after World War II by the Allies. For many years large amounts of chemical (and nuclear) material have been dumped in the bay by different countries. In 1960, Tabun shells recovered from the Little Belt were cast in concrete and dumped in the Bay of Biscay (Anon. 1993; Glasby 1997).

Dump sites outside Europe

Between 1945 and 1968 the US authorities dumped at least 100,000 tons of CW off the American east and west coast (a.o. California, New Jersey, West Virginia & South Carolina, Gulf of Mexico) (MEDEA 1997). Between 1968 and 1970 a number of large dumping operations were carried out on the continental shelf off the coast of New York and Florida (operation " CHASE - Cut Holes And Sink 'Em ") (MEDEA 1997).

Immediately after World War II thousands of tons of mustard gas were dumped off Nova Scotia by the Canadian Navy; in some cases the entire vessel was scuttled. Between 1959 and 1962 surplus American munitions were dumped along Canada's east coast by the US Navy (Myles *et al.* 2001). At present four munition dump sites are under lease to oil and gas exploration companies (Myles *et al.* 2002).

Off the coast of Japan large amounts of CW were dumped by the US occupation forces right after World War II. It is believed that prior to the end of the war, the Japanese Imperial Army also dumped CW on a regular basis. Many of the dump sites are situated close to the shore. Nothing is known about the quantity of the dumped war material or

exactly when these dumping operations were carried out (MEDEA 1997).

At the end of World War II a total of almost 15,000 tons of CW (mainly filled with mustard gas) was dumped off the Australian coast on at least three different locations. During the 1960's and 1970's a number of smaller dumping operations were carried out in Australian waters (Plunkett 1998).

Accidents

Over the last 50 years a large number of accidents related to sea-dumped CW have been reported in the Baltic, the North Sea, the Adriatic Sea and the Sea of Japan. Most accidents involved fishing crews; in some cases complete lumps of Yperite (mustard gas) were fished up, often resulting in serious burning wounds. Numerous incidents have also been reported related to the washing ashore of shells.

The largest number of accidents were reported by Danish fishermen in the Baltic Sea - as much as 450 accidents since 1976 (Theobald, this volume). The latter is most likely related to the policy in Denmark - fishermen are compensated for each shell that is recovered and brought onshore (HELCOM CHEMU 1994; Laurin 1997). In Sweden, where no such policy exists, the number of reported accidents is surprisingly low. This seems to indicate that most likely many accidents are not reported, and probably the shells are thrown back into the sea.

Local fishermen in the Irish Sea also regularly bring up munition in their nets. At least one fisherman was injured by explosives. In the 1990's thousands of small chemical and toxic explosives devices were washed up on the beaches of Northern Ireland and Scotland's west coast (a.o. Mull, Oban, Arran). The munition had most likely become dislodged as a result of pipe laying activities close to the Beaufort dump site; some people were badly injured when bombs they picked up on the beach ignited (Anon. 2001). A detailed survey was undertaken in the mid-90's; the results showed that large quantities of CW were dumped outside the charted dump site (SOAEFD 1996).

International policy

One of the first organisations to deal with the problem of sea-dumped CW in Europe was the Baltic Marine Environment Protection Commission (HELCOM). In 1992 the CHEMU (Chemical Munitions) *ad hoc* Working Group was established with the main purpose of reporting the information related to CW in the Baltic; Denmark acted in this as lead country. The general conclusions and recommendations of the CHEMU working group are discussed in this volume (Theobald).

HELCOM collaborates closely with the OSPAR Commission on the subject of sea-dumped CW. The OSPAR "Standing Advisory Committee for Scientific Advice" (SACSA) gathers all information in relation to munition dump sites and the possible recovery methods. Recently an *ad hoc* working group has been established which deals a.o. with (1) reporting, recording and assessment of encounters with marine dumped chemical weapons and munitions, (2) guidelines for fishermen and other users of the sea, and (3) surveillance and management practices; lead country is Ireland.

Also in Europe the Conversion For the Environment Foundation (CFE) has dealt with the problem of sea-dumped CW. The foundation is an international, non-governmental organisation with headquarters in the Netherlands and Russia. It focuses on acute environmental problems related to the defence industry, with specific attention for marine CW dump sites. In collaboration with NATO two workshops were organised on "Sea-dumped Chemical Munitions" in 1995 and 1996. The results of the first workshop were published in the book "Sea-dumped chemical weapons : aspects, problems and solutions" (Kaffka 1995).

The Chemical and Biological Warfare (CBW) Project of the Stockholm International Peace Research Institute (SIPRI) has carried out an extensive study of the CW problem, bringing together scientists from different European countries. The results of these studies have been published in 1997 in the book "The challenge of old chemical munitions and toxic armament wastes" (Stock & Lohs 1997).

In the beginning of the 1990's expert groups in Denmark, Sweden and Germany prepared several national reports on dumped chemical munitions in the Baltic Sea (HELCOM CHEMU 1994; Anon. 1993; HELCOM CHEMU 1993). Since the mid-90's an increasing number of studies have been carried out in Europe and Russia (e.g. Rapsch & Fisher 2000; SOAEFD 1996; van Ham *et al.* 2000; Missiaen *et al.* 2001; Muribi 1997; Emelyanov *et al.* 2000). Caused by a deep concern about Russian dumping operations in the arctic seas during the cold war, the United States recently carried out a detailed study of these CW dump sites (MEDEA 1997).

A number of scientists and international organisations believe it is best to leave the dump sites undisturbed, especially if they are in deep water. In 1994, HELCOM recommended that CW dumped in the Baltic Sea be left undisturbed and concluded that they pose no immediate danger to the marine environment (HELCOM CHEMU 1994). The large number of accidents reported in this area however seems to contradict this. Moreover, there are too many uncertainties to draw any firm conclusions. For instance, the rate of deterioration of the munitions is unclear, not all the dump sites are known, and the behaviour of the leaking warfare is not fully understood.

In most countries the "do not touch" policy still applies, and no actual measures have been taken against possible future environmental catastrophes. Up to now only two recovery operations were carried out in Europe - in the Little Belt in 1960, where two shipwrecks filled with Tabun shells were recovered, and in the German Wadden Sea in the 1950's, where due to increased demands for scrap dumped ammunition was recovered to be used in steel production. Although it is nowadays believed that recovery of dumped munition may in some cases be technically feasible, there are serious concerns about the high risks involved both for salvage crews and for the marine environment.

The Gent workshop

In the past, most field research has been focused on (1) tracing and documenting dump areas, often using conventional acoustic and magnetic techniques, and (2) screening of seabed sediments and water samples. In many cases the sampling sites were more or less picked at random, and screening was done for merely one or two chemical warfare agents, thereby often overlooking the fact that conventional weapons may as well contain highly

toxic substances.

Laboratory studies have up to now mainly paid attention to the stability of toxic warfare agents. Still, the marine ecosystem is not comparable with the laboratory environment, and little is known about the dynamic behaviour of pollutants under actual marine conditions, their environmental impact and possible bio-accumulation in fauna and flora (even after long periods of time some agents remain extremely hazardous).

During recent years, however, an increasing number of detailed investigations have been carried out in different countries (e.g. on corrosion research, pollutant release, ecotoxicity, geophysical monitoring, risk evaluation). In order to assess the latest state-of-the-art in marine dump site research and to allow the exchange of international experience and expertise in this complex matter, an international workshop was held in July 2001 in Gent (Belgium) on *"Chemical munition dump sites in coastal environments"*. The workshop was organised in the framework of the Belgian federal OSTC project "Evaluation of the Paardenmarkt site", an old hazardous military waste site off the Belgian coast.

The workshop was divided in 3 different sessions : status assessment, risk assessment, and policy. Each session was rounded off by a debate, which allowed to make maximal use of the present expertise and to confront advice and opinions.

Status assessment

Liebezeit focuses on munition dumped in the German Wadden Sea. Most of the dump sites (16 in total) are located in extremely shallow water. Estimates are that between 0.75 and 1.5 million tons were dumped here. Apparently there seems to be no clear danger but due to a lack of information this may be misleading - up to now no detailed sampling was carried out on the sites. On one dump site munition shells have surfaced and may form a possible threat.

Paka & Spiridonov present an overview of Russian surveys of dumped CW in the Baltic Sea and Skagerrak from 1997-2000. Near-bottom dynamics were studied as well as the chemical properties of the sea water. Dump sites were investigated using a.o. water and sediment samplers, side-scan sonar, magnetometer, and ROV's for inspection of sunken vessels. Numerous observations of leakage were made. However it is not known what proportion of dumped CW is leaking or how far the corrosion process has advanced.

Research into the transport routes to the Bornholm dump site is discussed by **Schultz-Ohlberg *et al*.** In order to save time large quantities of munition were dumped in the Baltic before the actual dump site was reached. Between 1994 and 1997 a total of 8 side-scan sonar and magnetometry surveys were carried out. About 100 objects were located; of these, 4 turned out to be munition on the sea floor, all the others were buried. A number of objects still remain unidentified.

Gorodnitski & Filin focus on Russian magnetometric investigations in the Baltic Sea and Skagerrak. The technique of precision magnetic gradiometry, used here in combination with side-scan sonar investigations, has allowed the exact localisation of 3 submerged vessels in the Bornholm Deep and 8 vessels in the Skagerrak Strait. This will finally allow better monitoring of these dump sites, and clearly illustrates the efficiency of gradient magnetic measurements for the investigations of munition dump sites.

The evaluation of an old WW1 munition dump site off the Belgian coast is presented by **Missiaen *et al***. An estimated 35,000 tons of warfare was dumped here, of which presumably one third contain chemical warfare agents. The munition is nowadays largely covered under accumulating fine-grained sediments, and most likely not too heavily corroded. At this moment there are no strong indications for acute danger but regular monitoring is needed.

The different presentations in this session make it clear that status assessment will highly depend on the site itself. Each site is unique - deep sites will differ a lot from shallow sites, and also the dumping methods will vary (e.g. loose munition vs. whole ships). A first step in each site assessment should therefore include detailed bathymetry and hydrographic investigations. The possibility to use new Navy technologies must be investigated, such as electro-optical lasers for geochemical detection.

It is worth pointing out that up to now all corrosion studies have focused on (sea) water, but we still don't know what happens in the sediment. As long as there is not more information available on these processes the only option is to sample regularly in order to check the migration of the toxic compounds. Still, a worst-case "sudden release" scenario does not seem very realistic.

The possibility to use mussels for biological monitoring should not be ignored, not only with respect to the search for chemical warfare agents but also for conventional explosives such as TNT and amatol, which are equally very toxic. It is stressed that upon degradation TNT will bind itself closely to the sediment. The question is also raised if techniques used for land sites, such as vapour analysis, can be applied at sea.

Risk assessment

Van Ham focuses on research carried out on conventional munition dump sites off the Dutch coast and in the Oosterschelde. Today it is recognised that there are a large number of toxic compounds present in conventional munitions. Depending on the site characteristics, location, type and quantity of munition, specific actions may be necessary. If no immediate action seems necessary at the moment, frequent monitoring will be mandatory to assure the safety of the environment and the public.

A study of the risks related to dumped CW in the Baltic is presented by **Theobald**. The chances for dumped munition washing ashore in the Baltic is estimated to be very low. There is a risk in the Bornholm Basin that chemical munition shells or lumps of viscous mustard gas can be caught in bottom trawl nets, hauled on board and thus cause contamination of the fishermen. All known cases of contamination to date were caused by viscous mustard gas. Risks to consumers from contaminated fish seem unlikely and have so far not been shown to exist.

Martin introduces the results of modelling studies of drifting objects (e.g. mines) at the sea surface and on the sea floor. This eventually allows to map the areas where munition is likely to reach the shores and beaches. Studies have shown that moving an object on the sea floor involves high current velocities. Different models are possible, such as scouring and burying. These models can help to evaluate what happens upon impact of the munition with the sea floor.

Waleij, Ahlberg *et al.* present an overview of the Swedish policy and discuss recent studies in Sweden on acute toxic effects of mustard gas and Clark. The results indicate that the acute toxicological danger of mustard gas is less than that of Clark. The minimum EC50-value is independent of temperature; the important factor is the exposure time. Sediment experiments indicated that Clark absorbs easily to sediment. Tests on *Nitocra spinipes* showed that the sediments were toxic even though the chemical analysis could not detect any of the substances.

As was the case for status assessment, the main question in risk assessment also seems to be whether the approach should differ from site to site or whether one general approach is possible. Is a different approach needed for dispersed sites and concentrated sites and should such approach also depend on the environment, or is some standardisation possible. In solving this question we may learn from former recovery actions.

A comparison with land studies could also help here. CW risk assessment for land contamination is done according to the source-pathway-receptor model (a hazard only becomes a risk if a pathway and sensitive receptor are present). This involves different steps : (1) Is there CW present : what, how much; (2) What is the public access to the site; (3) What is the public access to CW (possibly the last step can be applied to fishermen). Each step in the process is given a certain rating.

The need for some sort of risk modelling is stressed by many. In order to perform such complex modelling a detailed input data base is needed (hydrographic, sedimentology, chemical, …). Furthermore it is necessary to specify exactly the risks that need to be modelled : risks to the public - risks to the environment - risks to the sediments. Starting with a first, simple model, this can be extended along the way, thereby slowly moving towards a more detailed and accurate model.

Policy

The present policy in Norway on sea-dumped CW is discussed by **Paetzel**. In 1989 research was done on one dump site; only 5 (out of 38) shipwrecks were investigated; 13 water samples were taken. On the basis of these results it was concluded that there is no danger involved, and since then nothing has been done. Recent media attention raised the need again for further investigations. Nevertheless new working groups still keep referring to the incomplete (and therefore most likely unreliable) 1989 report.

The legal implications of sea-dumped CW and treaties involved are presented by **Zanders**. The Chemical Weapons Convention (CWC), which entered into force in 1997 aims at the world-wide destruction of all CW. However, it does not specifically encourage to remedy sites with CW dumped in bodies of water. Different classes of CW have their respective declaration and destruction obligations.

Reynders finally presents a discussion on the involvement of NATO in solving the problem of sea-dumped CW. In October 2000 a workshop was organised in Riga by the Eastland Coastal Maritime Operations programme on "Environmental and safety implications of the recovery and disposal of dumped ordnance in coastal waters". NATO is willing to participate in the coordination of future projects involving the inventory of dump sites and risk assessment standardisation.

During the discussion following this session the fact is stressed that no time should be lost and immediate actions must be undertaken very soon. The most important things to be done are to (1) set up an inventory of dump sites, (2) create an openness through public information and improved communication, (3) start up different monitoring programmes, and (4) take the first steps towards a risk assessment model.

It is clear that our present knowledge is not sufficient. More research is needed to assess the correct status of each site. However there is no general strategy for doing this, and each site will demand its proper strategy. New techniques must be investigated, and as long as not all the facts are known regular sampling must be carried out. Continuing fundamental research may ideally be done through international cooperation, including Russia (this will also help to increase the credibility). The resulting knowledge and information will also allow to further refine or tune the monitoring programmes.

Open flow of information is equally important. This will not only allow to increase the international public awareness, but it may also form a powerful argument in the political debate that is recently going on in several European nations. A first step should be to set up an inventory of CW dump sites. This will ideally necessitate the organisation of a network of NATO and PFP (Partnership For Peace) countries involved in this matter.

Conclusions

The main conclusions and recommendations of the workshop can be summarised as follows:

- Although many dump sites do not seem to pose an immediate risk, the lack of data and incomplete investigations often give rise to conflicting messages.
- More research (using novel techniques) is needed in order to (re-)assess the correct status of each dump site. As long as not all the facts are known regular monitoring and sampling must be carried out.
- Information on the exact amount and location of dumped CW often varies from one source to another. An inventory of European marine CW dump sites should be set up as soon as possible; support from the military (NATO) is essential in this.
- There is still very little information on the environmental risks. The state of corrosion, for example, may differ widely from one site to another. The possible hazards of each site need to be determined accurately.
- Steps must be taken for the development of a risk assessment model for marine munition dump sites; to this end the experience from land risk assessment models should be used.
- Sea-dumped CW are a border-transgressing problem; exchange of information and international cooperation are therefore crucial. The European Commission, for one, should provide financial support.

- Creating more openness and public awareness is of vital importance. Not only will this help to take away the incertitude and doubts on the subject, but it will also avoid over-concerned reactions.

Last but not least, it is clear that no strategic reflection can outstrip the ethical motives and common sense involved. This problem deserves the best of our capacities, both today and in times to come. This we owe to society and the future generations.

References

ANDRULEWICZ, E. 1996. *War gases and ammunition in the Polish Economic Zone of the Baltic Sea.* In: A.V. Kaffka (ed), Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions. NATO ASI Series, 7, 9-15.

ANON. 1993. *Chemical munitions in the southern and western Baltic Sea*. Federal Maritime and Hydrographic Agency, Hamburg, Germany, 65 pp.

ANON. 2001. *Munition dumping at Beaufort's Dyke*. Fisheries Research Services.

HELCOM CHEMU. 1993. *Report on the availability of correct information on dumped chemical munition on the Swedish Continental Shelf*. Report submitted by Sweden to the HELCOM CHEMU Working Group, April 1993.

HELCOM CHEMU. 1994. *Report on chemical munitions dumped in the Baltic Sea*. Report submitted by Denmark to the HELCOM CHEMU Working Group, March 1994, 43 pp.

DUURSMA, E. K. (ed). 1999. *Dumped chemical weapons in the sea - options*. Heineken Foundation for the Environment, 60 pp.

EMELYANOV, E.M., KRAVTZOV, V.A., AND PAKA, V.T. 2000. *Danger to life of areas of dumped trophy chemical munitions in the Skagerrak Sea and in the Bornholm Basin. Baltic Sea*. In: Local Agenda 21. Through Casc Method Research and Teaching Towards a Sustainable Future. München, Mering, 58-64.

FONNUM, F. 1993. *An investigation into the sunken chemical ships outside the Norwegian coast*. Norwegian Defence Research Establishment, Division for Environmental Toxicology, 16 pp.

FRONDORF, M. 1996. *Special study of the sea disposal of chemical munitions by the United States.* In: A.V. Kaffka (ed), Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions. NATO ASI Series, 7, 35-40.

GLASBY, G.P. 1997. *Disposal of chemical weapons in the Baltic Sea*. The Science of the Total Environment, 206, 267-273.

GRANBOM, P.O. 1996. *Investigation of a dumping area in the Skagerrak 1992.* In: A.V. Kaffka (ed), Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions. NATO ASI Series, 7, 41-48.

VAN HAM, N., VAN DOKKUM, H., AND BLANKENDAAL, V. 2000. *Beoordeling van de milieurisico's van gestorte munitie in de Oosterschelde - Bureaustudie op basis van metingen in 1999.* TNO Prins Maurits Laboratory, The Netherlands, Report 2000-A68, 42 pp.

KAFFKA, A. V. (ed). 1995. *Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions.* NATO ASI Series, 7, 170 pp.

LAURIN, F. 1997. *The Baltic and North Sea dumping of chemical weapons : still a threat ?* In: T. Stock & K. Lohs (eds), The challenge of old chemical munitions and toxic armament wastes. SIPRI Chemical & Biological Warfare Studies, Oxford University Press, 263-278.

MEDEA. 1997. *Ocean dumping of chemical munitions: environmental effects in arctic areas.* US Government Report, 235 pp.

MISSIAEN, T., HENRIET, J.-P. *ET AL*. 2001. *Paardenmarkt site evaluation - Final Report.* Federal Office for Scientific, Technical and Cultural Affairs (OSTC), 185 pp.

MURIBI, M. 1997. *Toxicity of mustard gas and two arsenic based warfare agents on Daphnia Magnia.* FOI Internal Report, ISSN 1104-9151, April 1997

MYLES *ET AL*. 2001. A study of the possible effects of proposed oil and natural gas exploratio activuities on ocean dumpsites of chemical warfare agents. Public review Commission on Licenses 2364, 2365 and 2368, 10 pp.

MYLES *ET AL*. 2002. Ocean dumpsites of chemical warfare agents in Atlantic Canada. Presented at the Commons Standing Committee on Fisheries and Oceans, March 2002, 7 pp.

OSPAR. 2002. *Overview of past dumping at sea of chemical weapons and munitions in the OSPAR maritime area*. OSPAR Commission.

PLUNKETT, G. 1998. *Chemical warfare agents (CWA) sea dumping off Australia.* Australian Hydrographic Service, 14 pp.

RAPSCH, H.-J., AND FISHER, U. 2000. *Munition im Fishernetz. Altlasten in der Deutschen Bucht.* Isensee Verlag, Oldenburg, 80 pp.

SOAEFD. 1996. *Surveys of the Beaufort's Dyke explosives disposal site,November 1995 - July 1996.* The Scottish Office of Agriculture, Environment and Fisheries Department, Marine Laboratory, Aberdeen, Scotland, 104 pp.

STOCK, T. 1996. *Sea-dumped chemical weapons and the chemical weapons convention.* In: A.V. Kaffka (ed), Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions. NATO ASI Series, 7, 49-66.

STOCK, T. AND LOHS, K. (eds). 1997. The challenge of old chemical munitions and toxic armament wastes. SIPRI Chemical & Biological Warfare Studies, Oxford University Press, 337 pp.