Building awareness of sea-dumped chemical weapons

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The SS *LeBaron Russell Briggs* sailed for the last time on 18 August 1970. Its cargo bay held, among other materiel, more than 12,000 M55 rockets, each of which was loaded with a little less than 5kg of sarin. US soldiers bored into the hull of the *Briggs*, allowing the incoming sea-water to force it downwards. The vessel came to rest just over 5,000m from the surface of the Atlantic Ocean, 400km east of Cape Kennedy, Florida. The sunken ship represented the end of Operation CHASE (Cut Holes and Sink 'Em), a US Department of Defense programme that disposed of unwanted munitions at sea.[1] To the custodians of chemical warfare (CW) materiel,[2] burial at sea seemed a better solution than disposal on land. At the time, a sea-bottom depository, far removed from populated areas, represented a reassuring sense of finality that land burial could not guarantee. In the aftermath of two world wars, more than one million tons of CW materiel came to rest on sea-bottoms throughout the world.[3]

The Chemical Weapon Munitions Dumped at Sea (CWMDS) database, created by researchers from the James Martin Center for Nonproliferation Studies at the Monterey Institute of International Studies, aggregates open-source accounts of nearly 50 years of CW materiel sea-dumping.[4] This article presents a short overview of the scale of the CW materiel problem and examines the persisting environmental and human health concerns resulting from the materiel still on the sea-bottom. Following this, it discusses the CWMDS database and how it helps to address these concerns, and briefly considers potential means for taking the project forward.

Chemical weapons dumped at sea

Faced with mountains of dangerous CW materiel, many policy makers considered sea disposal a safer alternative to land-based options, such as burial or incineration. The rationale for such activities was based on the belief that the vastness of the sea would mitigate any environmental or health risks posed by the CW agents. Many expected that the agents would lose toxicity over time through natural chemical decomposition, or if somehow released (e.g. through casing failure), would become so diluted that any remaining toxic properties would become negligible.[5]

From 1918 to 1970, the United States was responsible for dumping more than 350,000 short tons[6] (hereafter, tons) of surplus, damaged and captured CW materiel.[7] Other countries also

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participated in sea dumping, especially after the Second World War, when CW materiel was confiscated from Germany by France, the Soviet Union, the United Kingdom and the United States. Each country bore responsibility for disposing of the materiel found in its respective zone. The Western Allies relied heavily on sea disposal for this obsolete materiel. During this period, under orders of the United States occupation authority, Japan also dumped CW materiel off its coast. It should be noted that more documentation exists regarding the dumping performed by the United States (locations, amounts and kinds of materiel) than for the activities performed by any of the other states.[8] The materiel ranged from small to massive quantities of munitions and/or canisters, and was dumped in the Atlantic, Arctic, Indian, Pacific and Southern Oceans. Obsolete, damaged or malfunctioning conventional weaponry was frequently dumped as well.[9]

Contrary to expectations, this materiel has not remained inert on the sea-bed. Dumped munitions have been found floating or washed ashore. In 1946, during transport from La Serpe to Manfredonia Bay (Italy), a number of mustard bombs fell into the water. While some were recovered and dumped further out to sea, "later, bombs were discovered floating nearby and in the harbor …".[10] A similar case occurred in the Gulf of Mexico in the same year, when a mustard bomb was recovered after having washed ashore. It was a remnant of 33 munitions that had earlier been dumped 32km off the coast by the United States.[11] More recently, in 1983 fishermen trawling in shallow waters (not more than 200m) off the coast of Cape Moreton, Australia recovered a one-ton cylinder of sulfur mustard.[12]

Cases of encounters with sea-dumped CW materiel such as these intensified public fear of damage to marine and human life, as well as to coastal environments. These fears led to an international effort to legally end the practice of sea-dumping CW materiel. The last acknowledged US incident—the scuttling of the SS *LeBaron Russell Briggs* in 1970—terminated the United States' sea disposal practice for such materiel;[13] the US Ocean Dumping Act entered into force in 1972.[14] The International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also called the London Convention) entered into force in 1975 and currently there are 86 states parties.[15] Both laws prohibit the sea disposal of certain types of hazardous waste. In those countries possessing a CW materiel stockpile, more acceptable land-based chemical disposal and destruction methods have replaced sea-dumping.

Legislation helped to ensure that there would be no increase in CW materiel on the sea-bed: but hundreds of thousands of tons of materiel, already dumped, remain at the bottom of the sea and may pose a latent threat to marine and human life. CW materiel dumped at sea before 1985 is considered "abandoned chemical weapons" by the Chemical Weapons Convention (CWC)[16] and states parties are not required to declare or destroy abandoned chemical weapons; (the only declarations required for abandoned chemical weapons are for those buried on a state's territory after 1976).

Corroding and/or damaged containers pose too great a danger to warrant their retrieval from the sea-floor, therefore remediation (which might include recovery of the munitions or containers, in-place destruction, area quarantine or application of encapsulation devices) and clean-up efforts have not been actively pursued by any country. Instead, a handful of studies monitoring the environments around known dump sites have been performed, and new efforts, discussed below, are under way.[17] Sea-dumped CW materiel has already caused casualties, and with time it is likely that the dangers posed by this materiel will only increase: we remain ignorant of the effects that human disturbance of the sea-bed, such as deep-sea trawling, may have on dumped CW materiel,[18] and researchers have witnessed leaking containers—which is not entirely surprising considering that much of the materiel has sustained more than 50 years' exposure to corrosive and turbulent marine environments.[19]

Environmental and human health concerns

Because its density is greater than sea-water and its solubility in water is low, sulfur mustard agent leaked from a container can persist as globules on the ocean floor. The unique properties of each marine environment can cause chemical reactions that lead to the formation of salts on the surface of exposed or leaked sulfur mustard agent, perhaps prolonging its toxicity.[20] Several casualties and deaths among fishermen have resulted from exposure to such salt-encrusted sulfur mustard globules, which easily become ensnared in fishing nets. For instance, in Bari Harbour, in the Adriatic Sea, a total of 230 mustard exposure cases have been recorded (the most recent in 1997).[21] Fishermen trawling in the vicinity are most often the victims of exposure. The sulfur mustard responsible for the damage most likely came from CW materiel carried by the American freighter SS *John Harvey,* sunk by German aircraft in 1943, and CW agents dumped by US forces a few years later. The 1997 case is particularly worrisome because it provides evidence that sulfur mustard remains toxic after nearly 50 years—even after having leaked into a marine environment. Mustard globules caught in fishing nets near Japan account for over 100 cases of injury and 4 known deaths.[22]

There are little data on the environmental damage CW agents can cause. Little was known at the time that the decision was taken to dump CW materiel at sea, and this situation has not changed significantly. The risks may be higher today than when the dangers of the dumped materiel were first acknowledged because containment failure, due to corrosion, is thought to occur after 50 years;[23] dredging, fishing or underwater pipeline construction may speed the degradation of containers; and some CW agents may maintain toxic effects for longer than originally thought.

Recent scientific investigations suggest that the geochemical characteristics of sea-water may potentially extend the potency of some CW agents while yielding harmful degradation products from others.[24] If released into the marine environment, some CW agents' lifetimes are expected to be in the order of seconds to days (phosgene, cyanogen chloride), limiting their toxic effects after release.[25] Other CW agents' lifetimes when located in deep marine environments are still relatively unknown (hydrogen cyanide).[26] Of most concern are the nerve agents (e.g. sarin, VX), the blister agent sulfur mustard (1, 1'-thiobis[2-chloroethane]) and arsenic-containing irritants (Clark I, Clark II and adamsite), because they are predicted to persist for long periods in ocean waters.[27] CW agents of low water solubility could potentially accumulate in sufficient concentrations in sea-water to cause harm, but it is hard to predict. It is difficult to gauge lifetime and toxicity: the pH, temperature, pressure and chemical composition of marine environments can all affect dumped CW agents and all vary greatly by location. The effects of leaked CW agents on the environment and the local ecosystem are not clear: the potential for bioaccumulation of leaked agents in fish, for example, which could eventually enter the human food supply, is still being assessed.[28]

Recent risk mitigation efforts

In light of past exposures, and in preparation for those in the future, US policy makers have suggested activities that aim to further assess the dangers posed by CW agents in the seas and to catalogue exact locations of known CW materiel dump sites. To achieve the first aim, the US Congress enacted the John Warner National Defense Authorization Act for Fiscal Year 2007, which enjoins the US Department of Defense to research CW materiel dumping and assess the associated health and safety risks posed to marine and coastal environments surrounding the United States.[29] One project, the Hawai'i Underseas Military Munitions Assessment Project, funded under the Act, joins researchers from the University of Hawai'i and the US Department of Defense for the purpose of studying the health and environmental risks posed by the tons of lewisite, mustard, cyanogen chloride and cyanide dumped in the 1940s at sites near O'ahu. The team has been collecting samples for analysis, although the final report has not yet been published.[30]

Achieving the second aim is proving to be a more challenging endeavour. Data on sea-dumping activity is hard to obtain. Many dumping incidents were vaguely documented, often lacking precise details about locations and types, some were not documented at all.[31] Generally, disposals that took place in the years following the Second World War are better documented than those which occurred earlier. Even when documented, locations can be difficult to verify, taking into account the potential drift of materiel resulting from years of exposure to ocean currents. However, since clean-up or retrieval of CW materiel is considered unlikely, providing the public with easily accessible and up-to-date information regarding known dump sites seems worthwhile.[32]

The Chemical Weapon Munitions Dumped at Sea project

The CWMDS database contains information about 127 locations where CW materiel has been dumped. The CWMDS team drew upon a wide range of sources, the majority of which are records and reports from governments, international organizations and academia. The types of dumping varied greatly. Beaufort's Dyke, a 3km-long gorge located between Northern Ireland

and Scotland, for instance, represents one end of the spectrum—a total of 180,000 tons of CW materiel has accumulated at this site from several separate disposals.[33] The other end of the spectrum includes "accidental" sites, where leaking munitions were pushed overboard as an emergency measure to avoid exposing a ship's crew to their contents. The CWMDS database also contains accounts of more than 70 scuttled ships.

The CWMDS project's purpose is to raise public awareness of sea-dumped CW materiel. The database will serve to warn fishermen, marine engineers and the general public to avoid disrupting areas thought to contain dangerous substances. Therefore the project's primary objective was to select an easily accessible platform that would provide users with an accurate sense of the scope and size of dumping. The ideal platform would also allow users to view each site in relation to geographic reference points in order to contextualize the potential for human encounters with dump sites. The team envisaged three-dimensional representation as the best possible choice for data mapping. Google Earth was selected to map the dump sites as it is compatible with all the most popular computer operating systems and it already has a large number of users.

The CWMDS database also aims to inspire the conception of solutions to the problems caused by these dumps. By gathering all the data in one accessible location, and by mapping the data in such a way as to provide a thorough overview of the problem, CWMDS hopes to increase support for and facilitate the development of an effective response to the problem of CW materiel dumped at sea.

Taking CWMDS forward

The data have been plotted and the public are now able to "see" CW materiel sea dumps. What should be done next? One option is to make the data accessible to Global Positioning System (GPS) receivers. This would help fishing vessels, divers and others who frequently encounter the sea-bed to avoid locations that could potentially be polluted by CW materiel. Dissemination of the data could be aided by partnering with non-profit or government agencies that serve these groups. The usefulness of such a system depends on three partially known factors: the precision of the data, the ability to acquire more data and the relative importance of the data.

Data precision

Currently, the precision of the mapped dump sites varies greatly: data points range from quadrilaterals defined to minutes and seconds, through notes describing the cardinal directions taken by disposing vessels, to the body of water only being named.[34] Clearly, for somebody using a GPS receiver to check for the location of dump sites at sea, flagging an entire body of water would be too inexact to be meaningful. Researchers need either to utilize image transparency—or some similar graphic means—to indicate the precision of each data point or to acquire more detailed information to demarcate dump sites more accurately.

Data acquisition

CWMDS would benefit greatly from more precise data regarding the location of many dump sites, but the team is not currently in a position to gather information through direct measurements. The gathering of additional information on a poorly documented site depends upon our researchers' ability to interview witnesses or persons who documented a particular disposal site, or to gain support from groups—scientific, governmental or other—willing to obtain or provide new information from direct observations. The willingness of state and intergovernmental organizations to carry out remediation efforts depends greatly upon both generalized awareness of the issue and its perceived importance. At present, momentum toward remediation remains ensnared in a paradox. Public concern cannot be wrought because the potential dangers remain unquantified; the dangers are not being quantified due to a lack of interest by policy makers, which stems from the absence of public concern. We hope that by providing an interesting means to understand the issue, the CWMDS will help bring an end to this paradox.

Relative importance

Human fatalities have resulted from exposure to sea-dumped CW agents.[35] However, the CWMDS project team has refrained from reporting any aggregate numbers regarding casualties or deaths because of uncertainty about precise numbers. Rather, most of the data sources noted in the CWMDS focus upon locations and quantities of dumped materiel. As noted above, the current data regarding the health and environmental impacts of CW sea-dumping are limited, and the subject requires more and better data and further analysis. With more data on health and environmental issues, it will be possible to calculate the threat posed by these dump sites and thus the relative importance of locating—and publicizing the location of—CW materiel dump sites.[36]

Expanding the project

Conventional weapons materiel (and occasionally radioactive materials) was often disposed of alongside CW materiel.[37] The quantity of CW materiel disposed at sea, while immense, pales in comparison to the millions of tons of conventional munitions so disposed, and any attempt at remediation efforts in the oceans also needs to be cognizant of sea-dumped radiological material—a subject that has not received enough scientific attention. Expanding the mapping of dump sites and the analysis of the threats they pose to include radioactive material and large-scale conventional materiel dumps would be a valuable endeavour.

Concluding remarks

Moving beyond qualitative accounts of CW materiel disposal at sea is a difficult task. However, it is important, given the dangers posed by dumped CW munitions. The international community must increase its efforts to understand this health and environmental problem. Many aspects have not been sufficiently studied, and some have not been investigated at all. Three of the most urgent issues are the many uncharted dump sites, the lack of knowledge about the presence of CW agents in fish and any resulting effects, and the potential for reclaiming sea-dumped CW materiel for nefarious purposes.

Increasing corrosion, cumulative man-made disturbances and natural disasters could speed containment failure or help sweep the more than 350,000 tons of mustard agent closer to shore.[38] Such an event may induce exposure to unsuspecting coastal dwellers or tourists, or seriously harm marine ecosystems. Whether any state is adequately prepared to respond to such an incident remains unclear. We hope that the CWMDS database will inspire the awareness necessary to help prevent such a calamity.

Notes

1. William R. Brankowitz, 1989, *Meeting Notes: Summary of Some Chemical Munitions Sea Dumps by the United States,* US Environmental Protection Agency, p. 51; Josh Schollmeyer, 2006, "Chemical Weapons under the Sea", *Bulletin of the Atomic Scientists,* vol. 62, September–October, p. 11; V.J. Linnenbom, 1971, *Final Report on First Post-Dump Survey of the CHASE X Disposal Site,* Naval Research Laboratory, Chemical and Biological Defense Information Analysis Center, Ocean Sciences Division; Federation of American Scientists, Military Analysis Network, "M55 Rocket", 15 June 2000, at <www.fas.org/man/dod-101/sys/land/m55.htm>.
2. In this report, CW materiel comprises chemical weapon munitions, associated fuzes, and canisters, vials or containers of bulk chemical weapon agents.
3. Figure based on sum of values noted in: US Department of Defense, Historical Research and Response Team, 2001, *Off-Shore Disposal of Chemical Agents and Weapons Conducted by the United States,* Aberdeen Proving Ground, MD; David M. Bearden, 2006 (updated 3 January 2007), *US Disposal of Chemical Weapons in the Ocean: Background and Issues for Congress,* Congressional Research Service; G.P. Glasby, 1997, "Disposal of Chemical Weapons in the Baltic Sea", *Science of the Total Environment,* vol. 206, nos 2–3, pp. 267–273; Danish Environmental Protection Agency, 1994, *Report on Chemical Munitions Dumped in the Baltic Sea,* Report to the 15th Meeting of Helsinki Commission, Ad Hoc Working Group on Dumped Chemical Munitions, 8–11 March 1994.
4. In mid-2006, Caroline Ong, a Davis United World College Scholars Program intern, decided to investigate chemical weapon agents dumped into the oceans and the possible problems they have and are causing. Under Raymond Zilinskas, Director of the Chemical and Biological Weapons Nonproliferation Program at MIIS, she plotted coordinates of many dump sites and, where possible, identified their contents. After Ong completed her internship, Tamara Chapman, and later Benjamin Brodsky, carried on the investigation. Joshua Newman finalized the project in 2008. After nearly six months of part-time effort on the part of Zilinskas, Newman and Andreas Sepp, the Chemical Weapon Munitions Dumped at Sea database was released in August 2009.
5. V.J. Linnenbom, op. cit.; Geoff Plunkett, 2003, *Chemical Warfare Agent Sea Dumping off Australia,* Department of Defence, Australia, pp. 18–19.
6. One short ton weights approximately 907kg.

7. To calculate this figure, we relied on cases where either the weight was known or where we had a precise number of containers and type as well as the ability to calculate the weight of the container. For railway wagons we used 50 short tons per wagon; we used 300 short tons per barge; 227kg per M78 bomb; and 52kg per M70 bomb. Due to the already existing restraints on precision, our estimate did not include cases where the amounts of a certain munition or container type would not equal hundreds of tons, or where quantities of agents were given in gallons.
8. Linnenbom, op. cit.; Thomas Stock and Karlheinz Lohs (eds), 1997, *The Challenge of Old Chemical Munitions and Toxic Armament Wastes,* Oxford, Oxford University Press.
9. The author has first-hand knowledge that conventional munitions are still sea-dumped, but does not believe the quantities are of the same scale as disposals occurring during the era of CW materiel dumping.
10. US Department of Defense, Historical Research and Response Team, op. cit.
11. Bearden, op. cit.
12. Plunkett, op. cit.
13. US Department of Defense, Historical Research and Response Team, op. cit.
14. Officially entitled the Marine Protection, Research and Sanctuaries Act, it regulates all dumping in waters within the jurisdiction of the United States.
15. Bearden, op. cit.
16. Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction, Articles III(1)(*b*) and IV(17), agreed 13 January 1993.
17. E. Amato et al., 2006, "An Integrated Ecotoxicological Approach to Assess the Effects of Pollutants Released by Unexploded Chemical Ordnance Dumped in the Southern Adriatic (Mediterranean Sea)", *Marine Biology,* vol. 149, no. 1, pp. 17–23; G. Garnaga and A. Stankevicius, 2005, "Arsenic and Other Environmental Parameters at the Chemical Munitions Dumpsite in the Lithuanian Economic Zone of the Baltic Sea", *Environmental Research, Engineering and Management,* vol. 3, no. 33, pp. 24–31; Linnenbom, op. cit.
18. Garnaga and Stankevicius, op. cit.
19. Amato et al., op. cit.
20. George O. Bizzigotti et al., 2009, "Parameters for Evaluation of the Fate, Transport, and Environmental Impacts of Chemical Agents in Marine Environments", *Chemical Reviews,* vol. 109, no. 1, pp. 236–256.
21. G.O. Bizzigotti et al., 2005, "Ocean Dumping of Chemical Weapons", *Noblis,* <www.noblis.org>.
22. Compiled from H. Kurata, 1980, "Lessons Learned from the Destruction of the Chemical Weapons of the Japanese Imperial Forces", in Jozef Goldblat et al. (eds), *Chemical Weapons: Destruction and Conversion,* London, Taylor & Francis, Stockholm International Peace Research Institute, pp. 77–93.
23. Xin Zhang et al., 2009, "Geochemistry of Chemical Weapon Breakdown Products on the Seafloor: 1,4-Thioxane in Seawater", *Environmental Science and Technology,* vol. 43, no. 3, pp. 610–615.
24. Bizzigotti et al., 2009, op. cit.; Zhang et al., op. cit; Jonathan B. Tucker, 2001, "Chemical Weapons: Buried in the Backyard", *Bulletin of the Atomic Scientists,* vol. 57, no. 5, pp. 51–56.
25. Bizzigotti et al., 2009, op. cit.; Danish Environmental Protection Agency, op. cit.
26. Bizzigotti et al., 2009, op. cit.
27. Bizzigotti et al., 2009, op. cit.; Amato et al., op. cit.
28. This issue has been discussed for some time. One recent ecotoxicology study (Amato et al., op. cit.) found arsenic and CW agent breakdown products in sediment surrounding known leaking CW dumped materiel. The study also found arsenic levels higher than the US Food and Drug Administration limit for food (2.6 mg kg^{-1}) in the tissues of fish near the location of the materiel, and much higher than those found in fish from a reference area far removed from the CW dump site. Interestingly, the researchers also noted physical characteristics, such as histological lesions in fish species collected close to the dump site—a finding they presume may have resulted from exposure to blister agents. Another report focusing on the Baltic Sea showed less conclusive results regarding the arsenic levels within marine organisms, but

did find higher arsenic concentrations in the sediments close to a CW materiel dump site (Garnaga and Stankevicius, op. cit.).

29. John Warner National Defense Authorization Act for Fiscal Year 2007, HR 5122, Title 3B, §314 became law on 17 October 2006. The act requires the US Secretary of Defense to conduct sampling at no less than six locations (two near the Atlantic coast, two near the Pacific coast and two near the Hawaiian Islands).
30. For more information, see the web site of the University of Hawai'i and US Department of Defense's Hawai'i Undersea Military Munitions Assessment Project at <www.hummaproject.com>. See also William Cole, "Army Taking Closer Look at Ordnance Dumps Off Oahu", *Honolulu Advertiser,* 30 October 2008; Gregg K. Kakesako, "Army Analyzes Data from Offshore Dump", *Star Bulletin,* 5 April 2009.
31. The lack of documentation stands as perhaps the largest issue facing those concerned about sea-dumped munitions. Possibly the most significant instance of poorly documented disposal is noted by Lev Alexandrovich Fedorov in his 1995 article, "The Undeclared Chemical War in Russia: Politics versus Ecology", Center for Russian Ecological Policy. Federov notes that approximately 150,000 tons of chemical weapon materiel was dumped by the Soviet Union in the Barents and Kara Seas.
32. Emily E. Baine and Margaret P. Simmons, 2005, *Mitigating the Possible Damaging Effects of Twentieth-Century Ocean Dumping of Chemical Munitions,* Huntsville, AL, US Army Engineering & Support Center.
33. Vic Rodrick, "Sea Shells: Deadly Harvest of Munitions is Washed up on Scotland's Beaches," *Red Orbit,* 1 October 2006; Rob Edwards, "Danger from the Deep", *New Scientist,* 18 November 1995, p. 1616; D. Hencke, "Details Released of 71,000 Bombs Dumped at Sea; Operation Sandcastle in the Fifties Disposed of Nerve Gas and Chemical Weapons", *The Guardian,* 28 March 1995, p. 2.
34. For examples of this range in precision, see Brankowitz, op. cit.; Oslo–Paris Commission, 2005 (revised), *Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area,* Biodiversity Series, p. 11; Rob Edwards, op. cit., respectively.
35. Kurata, op. cit.
36. Thomas Stock, 1995, "Sea-dumped Chemical Weapons and the Chemical Weapons Convention", in Alexander V. Kaffka (ed.), *Sea-dumped Chemical Weapons: Aspects, Problems and Solutions,* Dordrecht, MA, Kluwer Academic, p. 59.
37. Among many others, see Schollmeyer, op. cit; Brankowitz, op. cit., pp. 45–47.
38. The 350,000 tons estimate was obtained by summing all instances of known values for mustard agent alone. However, it must be noted that many records mention that mustard was only one portion of the tons of agent disposed.