

ENVIRONMENTAL THREATS POSED BY THE SEA-DUMPED AND EARTH-BURIED CHEMICAL WEAPONS IN THE CENTRAL-EUROPEAN AND BALTIC REGION

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Abstract

Beside chemical munitions that can be occasionally found till now on former European battlefields of the WW-I (mainly in Belgium, France and Poland) and on the Asian battlefield of the Japan aggression in 1937 and WW-II (in China), there are several sites of concern at former production, storage, training and disposal sites with exactly unknown types, number and status of old and abandoned chemical munitions. The largest terrestrial site in the Central Europe with earth-buried chemical weapons (CW) of various origin from the WW-I and of German origin from the WW-II is the Munster/Oertze area in Lower Saxony. Captured German CWs were disposed mainly by sea-dumping (some also by open-pit burning) under supervision of Allies after WW-II. CW from the US, GB and partially also F occupation zones loaded on commissioned ships were sunken in Skagerrak, Norwegian trench and SW of Bornholm. The CWs from the SU zone were dumped by throwing them overboard in the SE part of the Gotland cavity and NE of Bornholm. Relevant data on the captured and sea-dumped CW inventory as well as precise coordinates of all dumping sites (for the long time matter of secrecy) are presented. Environmental threats posed by the sea-dumped CW munitions are assessed according to the munitions types and CW fillings utilising data on corrosion, leakages, dissolution, hydrolytic breakdown and ecotoxicological effects in sea and benthic biota of the Baltic ecosystem. The long-term environmental threats can be considered as significantly lower as compared with the risks of lifting the corroded items, transportation and destruction according to the current workplace safety and environmental protection standards as required by the Chemical Weapons Convention (CWC).

Introduction

Toxic warfare remnants of used and abandoned chemical ammunition and non-adequately destroyed/disposed chemical warfare agents, both in munitions and in bulk in former production facilities as well as on storage and disposal sites belong to the dangerous heredity of the past chemical arsenals produced and used on the European and Far-East battlefields since the first use of chemical weapons in 1915. In only rare cases, states responsible for the left munitions under their former jurisdiction either have already destroyed these inventories (The Netherlands in Indonesia in the 1980s) or are obliged to do it now (e.g. Japan in China) pursuant to The Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Chemical Weapons Convention, CWC), opened for signature in Paris, January 13, 1993, entering into force on April 29, 1997 containing *inter alia* stringent requirements on the destruction technologies with regard to workplace safety and environmental protection. The Convention does not allow methods routinely used even after WW-II when the CW inventories of Nazi German Forces and Imperial Japanese Forces were destroyed by open pit burning, earth burial, exceptionally explosions and mainly sea dumping. It can be noted that the last known ocean dumping was performed by the US in the Caribic (Operation CHASE - munitions filled with nerve agents) in the 1970s. Strong national and international criticism was the impetus to build an incineration plant for safe destruction of outmoded chemical munitions in the US. Preparations for destruction of chemical weapons (CW) pursuant to the CWC have initiated developments of a couple of alternative destruction technologies worldwide, mainly at the current leading possessors of CW arsenals (Russia and the US), smaller possessors (India, South Korea) as well as in countries with findings of old and abandoned CW (Germany, France, Belgium, Poland, China) or in states responsible for the abandoned CW (Japan).

This paper reveals some generally unknown facts on the production and uses of chemical warfare agents and chemical weaponry during the WW-I, in the inter-war period and during the WW-II. Facts on origin and locations of inadequately destroyed/disposed chemical weaponry in the Central-European, mainly Baltic Region after WW-II are presented. Environmental threats posed by these toxic warfare remnants are assessed.

Production and use of chemical weapons on European battlefields in the WW-I:

After some more-or-less random use of various irritants (mainly lachrymators) already in 1914, the massive use of toxic warfare agents has been developed since the first use of chlorine at Ieper (Ypres) on April 22, 1915. Volatile lung injurants (asphyxiating, choking agents), like chlorine (CL), phosgene (CG), diphosgene (DP) and chloropicrin (PS) belonged to the mostly employed agents. CG itself was responsible for about 60 % of all war casualties caused by chemical agents. The other group were harassing agents (irritants). Among them a numerous family of tear gases or lachrymators (halogenated compounds of various kind), such as chloroacetophenone (CN), xylylbromide, bromobenzylcyanide (BBC), bromoacetone, bromoethyl acetate and like, can be named. A smaller group was represented by sternutators (vomiting gases), mainly aromatic arsenicals, such as diphenylchloroarsine (DA), diphenylcyanoarsine (DC) and adamsite (DM) irritating upper breathing ways and causing intolerable coughing and sneezing. Also generally toxic agents such as hydrogen cyanide (AC) and cyanogen chloride (CK) and like occurred on battlefields. The last step in the development during WW-I was the group of skin-corroding compounds (vesicants, blister agents), i.e. methylchloroarsine (MD), ethylchloroarsine (ED) and the most effective mustard gas (H). The list of used compounds totalled with something over 40 compounds and consequently, a very wide list of technical means of delivery to targets can be compiled.

The CW agents (CWA) production during the WW-II was 136 000 tons in total (113 000 t of lung injurants, 12 000 t of vesicants, 6 600 t of sternutators and 5 500 t of lachrymators).

Total use of CWA was 113 000 t (Germany 52 400, France 26 300, Great Britain 14 400, Austria-Hungary 7 800, Italy 5 300, Russia 4 700 and USA 1 000).

During the WW-I, the used CWA caused 1 297 000 casualties, 91 200 of them lethal (1).

Production in Europe of chemical weapons before and during the WW-II:

Germany, USSR, France, United Kingdom and Italy belonged to the leading producers and possessors of CW in Europe before the WW-II, all of them having a wide assortment of chemical weaponry, stressing the offensive chemical assets, such as artillery and aerial munitions (witnessed e.g. by Italian use in Ethiopia already in 1935). To the relatively small producers with a very limited retaliation-in-kind capability belonged reportedly Poland, Hungary, Czechoslovakia, Yugoslavia, Rumania and Greece, many of them without then typical offensive artillery and aerial means (2). Czechoslovakia, e.g. possessed only 20 t of mustard (in bulk) of own production (to complement the border fortification with contaminated areas with spraying devices and land mines) without any munitions and small amounts of irritants (to be used in smoke candles) imported from the US and Italy (2.5 t of diphenylchloroarsine, 1.0 t of adamsite and 2.7 t of chloroacetophenone) in 1937 (3).

For the topic of this paper, the most relevant are information on the German production before and during (and on the status of this arsenal at the end of) the WW-II. Soon after the end of WW-I the German military (*Reichswehr*) became convinced that the 1919 Treaty of Versailles was so humiliating for Germany that another war was inevitable. A so called "struggle for liberation" was expected to start in the years just after the war. German military strength has been greatly weakened and it would not have been possible to increase Germany's conventional weapon capability rapidly. Instead CWA were considered as a possible way to compensate for the lack of conventional capability. Experiences in WW-I had also demonstrated the effectiveness of CW. That is why the preparation for the production of CWA began as early as 1923 and the mass production programme started in the *Third Reich* after the power-seizure by Nazis. New agents emerged, such as N-mustards and as a result of research programme of IG-Farben on the new compounds of fluorine and phosphorus, originally oriented to new systemic pesticides, two interesting groups of toxic agents were synthesised within the framework of a secret research: The first were aliphatic compounds of fluorine, analogues and homologues of 1-fluoroacetic acid with selective toxicity against rodents. The other, initiating the era of very effective organophosphorus pesticides with anti-cholinesterase activity gave rise to the new group of super-toxic lethal nerve agents in the late 1930s, in the first line of tabun (GA), sarin (GB) and soman (GD). The first compound was routinely produced during WW-II including its filling in munitions; the second one reached the stage of pilot-plant production. Detailed data on production, storage and testing sites

and munitions types were compiled by intelligence services of Allies after WW-II. As for the volumes produced during the *Third Reich*, data from various sources differ only slightly for individual agents and in total. The reliable figures as shown in Table 1 have been presented by B. Appler in (4) recently.

Table 1. Production of chemical warfare agents (CWA) in Germany during the *Third Reich* (4)

CWA	Quantity in tonnes
S-mustard	27 597
Arsine oil ^a	7 500
Tabun	12 000
Phosgene	5 900
N-mustard	1 928
Irritants ^b	12 633
Total	67 557

Notes: ^a Unrefined mixture of arsenic trichloride, phenyldichloroarsine, diphenylchloroarsine (Clark I) and trichloroarsine used to produce Clark I and as an admixture for S-mustard to lower the freezing point.

^b Diphenylchloroarsine, adamsite, chloroacetophenone, etc.

Data on chemical weapons, captured by Allies in munitions and in bulk were generally reported in the weight parameters including also metallic casings (to be distinguished from data on the weight of CWA *per se*). The amount of CWA in munitions is taken to be 15 – 30 %, but it may vary from 5 to 50 % in some cases (5).

Disposal of German chemical weapons captured after the WW-II:

According to the documents in the Federal Archives at Koblenz, as reported by B. Appler (4), quantities of chemical munitions found, destroyed, captured or recycled (and it is to be added: and transported away from Germany) in the four occupation zones by the end of 1947 were: 93 995 t in the US zone, 122 508 t in the British zone, 9 250 t in the French zone and 62 505 t in the USSR zone. Of the total 288 258 tonnes of captured munitions, 269 000 tonnes were destroyed or otherwise used by the end of 1947. The Russian report (7) quoting the Potsdam Conference gives a little-bit higher figures, referring beside chemical ammunition also on chemicals found in bulk: 104 500 t in the US zone, 126 000 t in the British zone, 9 500 t in the French zone and 70 500 in the USSR zone, i.e. in total 311 200 tonnes of CW inventory.

The Agreement of Potsdam Conference of August 2, 1945 outlined in general terms the way in which Germany was to be demilitarised and the manner in which its weapons and munitions were to be destroyed or to become the property of the Allied forces (4). Each occupation authority was responsible for disposing of the stocks found in its zone, and, consequently, each formed its own organisation. The accuracy of data from the immediate post-war period was affected by the circumstances under which the disposal operations were conducted. Nevertheless it is without any doubt that the stocks were disposed primarily (approximately 250 000 tonnes) by dumping them into the North and Baltic Sea. It is estimated that between 42 000 and 65 000 tonnes were dumped into the Baltic Sea. Considerable quantities were destroyed on the spot (mainly by open-pit burning). Munitions filled with CWA that could not be transported were blown up. Large quantities of these weapons were also transported from Germany. So, e.g. over 34 000 tonnes of munitions were transported from the US zone to various countries, mostly to the USA and some to Canada, 3 100 tonnes were transported from the French zone to France. Additionally, there were 30 345 German chemical munitions units filled mostly with N-mustard found in Austria. The preferred method used by the Western Allies was to load the weapons on damaged ships and to sink them in deep water. The British and US occupation authorities sank one ship loaded with CW in the European polar zone and 42 ships at two dumping grounds – the Norwegian trench (near to Arendal, depth about 700 m) and in the Skagerrak, (about 25 nautical miles off the lighthouse Maseskär near Lysekill, Sweden, depth about 200 m) (4). Beside, unknown quantity of CW inventory was sunk by the US and British authorities in the Atlantic, and small amount near Helgoland according to F. Fonnum (4). The UK reports contain no other sites in the Baltic Region. But according to witnesses, also 4 ships containing

15 000 t of CW munitions were sunk southwest of Bornholm under the supervision of the British Military Administration (5).

There are no exact data on the French disposal operations, it is however reported that about 1 500 tonnes of organoarsenic irritants were dumped under French supervision in Skagerrak (5).

USSR used for the dumping operations two sites, both in the Baltic proper: The first was the south-eastern part of the Gothland cavity, about 65 nm SW from Liepaya (Latvia) with the depth 110 – 120 m, the second one about 35 nm NE of Bornholm (Denmark) with the depth 75 – 105 m. In the first, about 2 000 tonnes of chemical munitions (48 392 munitions units containing 958 t of CWA) were disposed, in the second, about 35 000 tonnes of munitions (560 090 units with 11 077 t of CWA) were dumped. It is to be stressed that the only recent Russian report gives exact data on numbers and fillings of the CW inventory (7). Some munitions stemming from these operations were detected on the waterways to the dumping sites from the north-German ports Wolgast and Peenemünde Ost where CW munitions were loaded, beginning north of Dziwnow. It is possible to summarize that the CW inventory disposed under the supervision of the USSR in the Baltic contained altogether 7 635 t of mustard gas, 1 552 t of adamsite, 2 209 t of other arsenicals, 559 t of chloroacetophenone and 80 t of other agents (including Cyklon B used in the German concentration camps). On the other hand, British and US archives have remained largely closed to the public until recently. Secrecy in the UK has made investigation difficult, while some US material has been reportedly destroyed (“because of lack of storage space”) according to H. Heintze (4).

With regard to sunken chemical munitions in the Baltic Region, one report appeared also after WW-II on one strange dumping site in shallow water (depth less than 30 m) of the Southern Little Belt. Obeying the order by the Field-Marshal Keitel that CW inventory should not fall in the enemy hands, German troops sunk there about 5 000 tonnes of CW munitions filled with tabun and phosgene before the end of WW-II. These munitions were however raised in 1959-60, encased into concrete blocks and subsequently sunk in the Bay of Biscay (5).

The experience of Allies with sea-dumping as the principal method for disposal of captured chemical warfare inventories in Germany was successfully used after capitulation of Japan (6).

Beside sea-dumping and consequent long-term health and environmental problems in a relatively closed Baltic aqueous ecosystem, there are also some sites with endangered terrestrial ecosystems. If we put aside relatively scattered small areas of CW findings on the former WW-I battlefields, rare remnants of CW e.g. in Poland, containing mainly arsenicals, as mentioned by Z. Witkiewicz and K. Szarski (4) and already mostly cleaned-up sites of former CW-production facilities, storage and training sites in the Central European region, mainly on the German soil, there is at least one heavy polluted site to be noted, reflecting the whole CW warfare history: Munster area (6500 hectares) in Lower Saxony, used by *Reichswehr* since the WW-I times just before the first CW use for production, storage and training, known as *Gasplatz* Breloh, in the times shortly after WW-I for the destruction of German and also Allied CW accumulated there; then since the 1920s again for preparing offensive chemical assets for use by *Wehrmacht* in the WW-II as *Munsterlager* and *Heeresversuchsstelle* Raubkammer (by the way, also for production of sarin). This area is currently used by *Bundeswehr* and the Federal Institute for Protection Technologies is located here also. Beside massive contamination due to the former activities, two hazardous events occurred here: It was an extremely large-scale accidental explosion of accumulated chemical munitions on October 1919, destroying 48 buildings (production facilities for asphyxiating agents and vesicants), approximately 1000 t of CWA, one million chemical shells, 230 000 chemical land mines and 40 railway tank-wagons loaded with CWA. This explosion and the tests conducted during WW-I contaminated the site Munster-North with toxic agents including arsenicals till nowadays. Shortly after WW-II, the production and storage facility at Raubkammer was exploded by the British Royal Engineers so that now, there is a dangerous mixture of munitions and their debris of various types and fillings, both filled and unfilled, with and without explosive, with and without fuse etc. in various depth of the sandy soil of this part of Lüneburger Heide including collateral pollution endangering ground water with toxic pollutants, especially with the arsenicals. It was estimated in the early 1990s that complete clean-up of this area could last for at least thirty years of very extensive and dangerous activities encompassing detection, excavation, transportation and finally destruction. At the time being, already the second incineration plant (using the effective plasma-torch technology with a very high workplace safety design delivered by Mannesmann) was put into operation for safe destruction in Munster. Another CWA polluted site in

an urban area was the Spandau Citadel in Berlin which has been fully cleaned-up in the 1990s, as reported by W. Spyra (4).

Environmental threats posed by the sea-dumped and earth-buried chemical weapons:

The health and environmental threats of the sunken chemical warfare inventory depend on the munitions types, kind of CWA and environmental conditions (prevailing temperature, water composition, character of sea-bottom etc.). The release of CWA into sea water is determined by thickness, composition and construction of metallic casing, influencing type and speed of corrosion, possible leakages and like. Release of CWA proceeds generally very slowly through small holes and leakages, the released agent is readily mixed with water creating thus only very low concentrations. The risk posed by concrete CWA (and present admixtures) is given beside its toxicity (ecotoxicity) by its solubility, hydrolysis in sea water, interactions with sediments etc. For the health and environmental threats of the earth-buried munitions, similar considerations are valid (including the possibility of explosions).

Sea-dumped munitions containing **phosgene** releases this compound, which readily decomposes to hydrochloric acid and carbon dioxide, creating thus negligible environmental threat. **Tabun** was contained in the munitions sunk mainly in Norwegian trench and Skagerrak. The German munitions fill contained about 20 % of chlorobenzene (for stabilising) which enhances otherwise good water solubility of the active agent (120 g/L). Dissolved tabun hydrolyses relatively rapidly (half-life 8.5 hrs at pH 7 and 20° C) forming another toxicant – hydrogen cyanide. In spite of the high acute toxicity of tabun and hydrogen cyanide and ecotoxicity of chlorobenzene, neither traces of these compounds nor any damages of marine biota were found obviously due to the long time of release. Sampling and chemical analysis performed by Norwegians did not detect any traces of the original fill according to Fonnum (4). Some health and environmental threats are posed by **mustard gas** (especially viscous mustard with addition of a resinous-like substance), due to its freezing point (13.8° C for pure substance) and limited solubility. Its maximum content is about 0.07 % at 20° C. At lower temperatures, typical for the bottom layers of sea water (0° C), the solubility decreases to 0.03 %. The relatively rapid mustard gas hydrolysis in sea water depends on the dissolution rate. At heterogenic conditions, the hydrolysis rate is about 0.01 min⁻¹ (0° C). The released mustard gas can therefore remain at the bottom layers in a form of slowly decomposing jelly-like spots in the sites of dumping, producing a long-time danger. Swedes have found sulphur mustard and its toxicologically harmless degradation product thiodiglycol near the shipwrecks in Skagerrak in the concentrations of the ppt-range. 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 (5). Russians tested toxic effects of low concentrations in fish (*Poecella reticulata*), zooplankton (*Daphnia magna*) and gastropod molluscs (*Lymnaea stagnalis*), showing no effects in fish, no effects in gastropods and 67 % lethality in zooplankton at 0.33 mg/L (in 1 day) and 33 % lethality in zooplankton species at 0.0033 mg/L (in 3 days) (7). Aromatic **arsenicals**, generally almost not soluble in sea water will stay at the bottom as solid sediments washed out by sea streams. The main process will be a slow solution and a heterogeneous hydrolysis. The concentration of arsenic determined in the neighbourhood of sunken munitions was only by one order higher than its background concentration in the Baltic (8). Similar behaviour (without As toxicity and its entrance into food chains) is expected in case of **chloroacetophenone**. The Russian study has found no lethal effects of water over adamsite and chloroacetophenone in quoted animal species (7). In case of buried munitions, slow release of toxic agent and local contamination of the soil layer and consequently of ground water represent the health and environmental danger. For both, sea-dumped and soil-buried munitions another danger exists like for any old and abandoned items, i.e. possibility of explosion or sudden release of toxic agents at any manipulations.

Conclusions:

In spite of (nowadays relatively rare) findings of old munitions on the former European battlefields of the WW-I, there is more relevant information on the production, storage, training sites including the fate of captured German munitions, mainly on the sites of their sea-dumping. This is due to the increased confidence and security measures within the international community thanks to the implementation of the Chemical Weapons Convention of 1993, entered into force in 1997. Moreover, in the Central European and Baltic Region, the contribution of HELCOM CHEMU (*Ad hoc* Working Group on Dumped Chemical Munitions of the Baltic Marine Environment Protection Commission of the Helsinki Commission) cannot be overseen. The study by SIPRI (Stockholm International Peace Research Institute) (4) and a pilot study by NATO/CCMS (Committee for the Challenges of Modern

Societies) (5) heavily contributed to elucidation of this problem and to realistic conclusions on contemporary and future concerns and challenges.

It can be estimated that slow release of CWA and their degradation products creating small concentrations in ambient aquatic milieu can last for another tens to hundreds of years in cases of slowly corroding thick-wall munitions while it seems more dangerous to try to raise the munitions for safe destruction from the current dumping sites. It is necessary to take precautions at any activities in nowadays known zones of dumping including fishing (not to allow using trawl nets sliding on the sea bottom which can lift dangerous munitions items and contaminate personnel). It is also without any doubt that a long-time monitoring at areas of concern is needed.

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