Paardenmarkt Bank, a WWI ammunition dump site off the Belgian coast

Tine Missiaen

Although this topic pops up in the press from time to time, surprisingly few people are aware that there is a WWI ammunition dump site off the Belgian coastal town of Heist. The figures are perplexing: at least 35,000 tonnes of German ammunition, at least a third of which are chemical shells, located at only a couple of kilometres from the esplanade! Yet there still are many gaps in our knowledge and it turns out that these are not easy to fill.

What has happened, has happened...

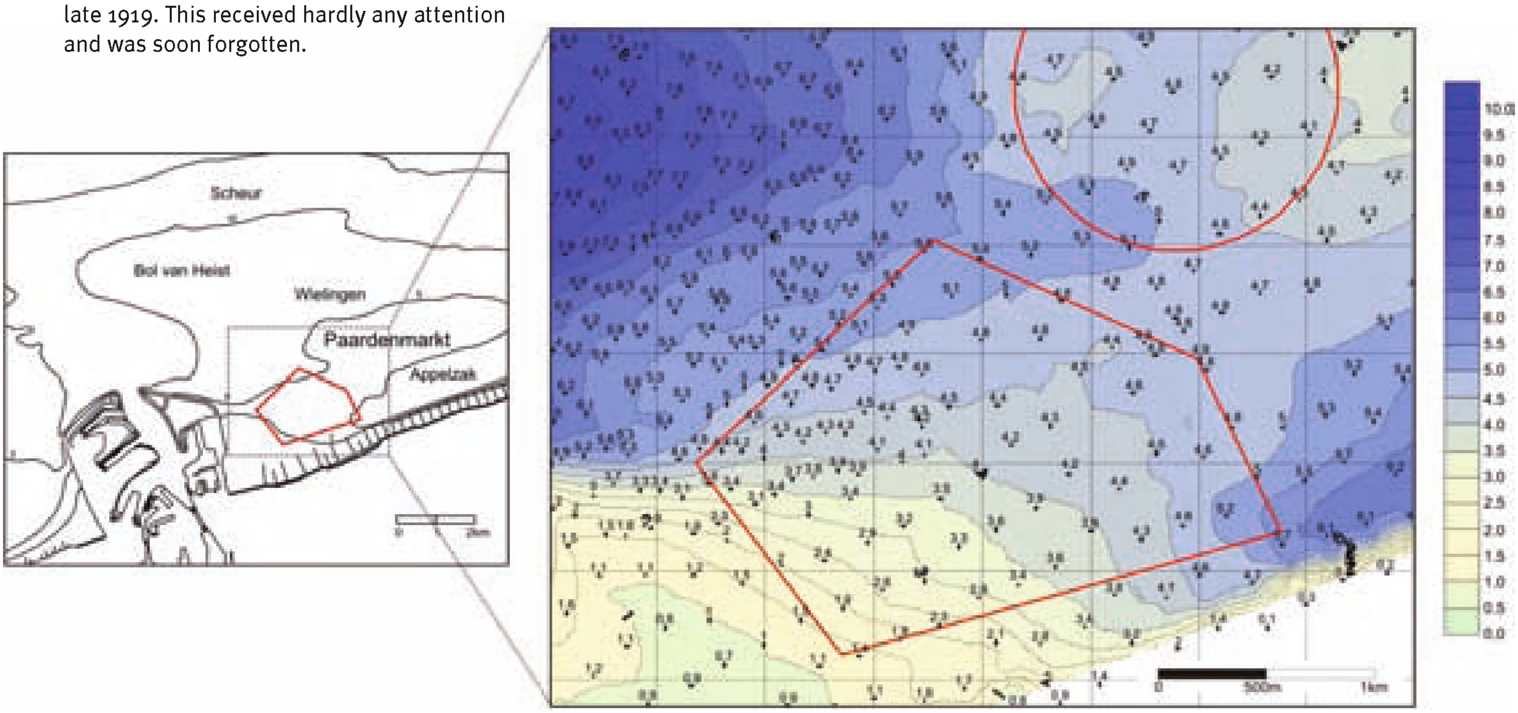
Very large quantities of explosives were left behind all over Belgium after the First World War. Their collection and preliminary storage in ammunition depots created extremely dangerous situations, resulting in many fatal accidents. As the situation gradually became intolerable and the disposal of ammunition on land still involved too many risks, the Belgian government decided to dump the ammunition in sea in late 1919. This received hardly any attention and was soon forgotten.

During dredging operations east of the port of Zeebrugge in 1971, various obstacles were found on the seabed. Extensive investigations by Navy divers in 1972 revealed ammunition including a number of chemical shells on 17 different sites. The first exploratory seismic and magnetic investigation of the ammunition dump site was conducted in 1988. On the bases of the results, the area was represented on hydrographic charts as a pentagon (with a total surface area of approx 3 km²) with an anchor and fishing ban (see chart). Other measures were not imposed at that time.

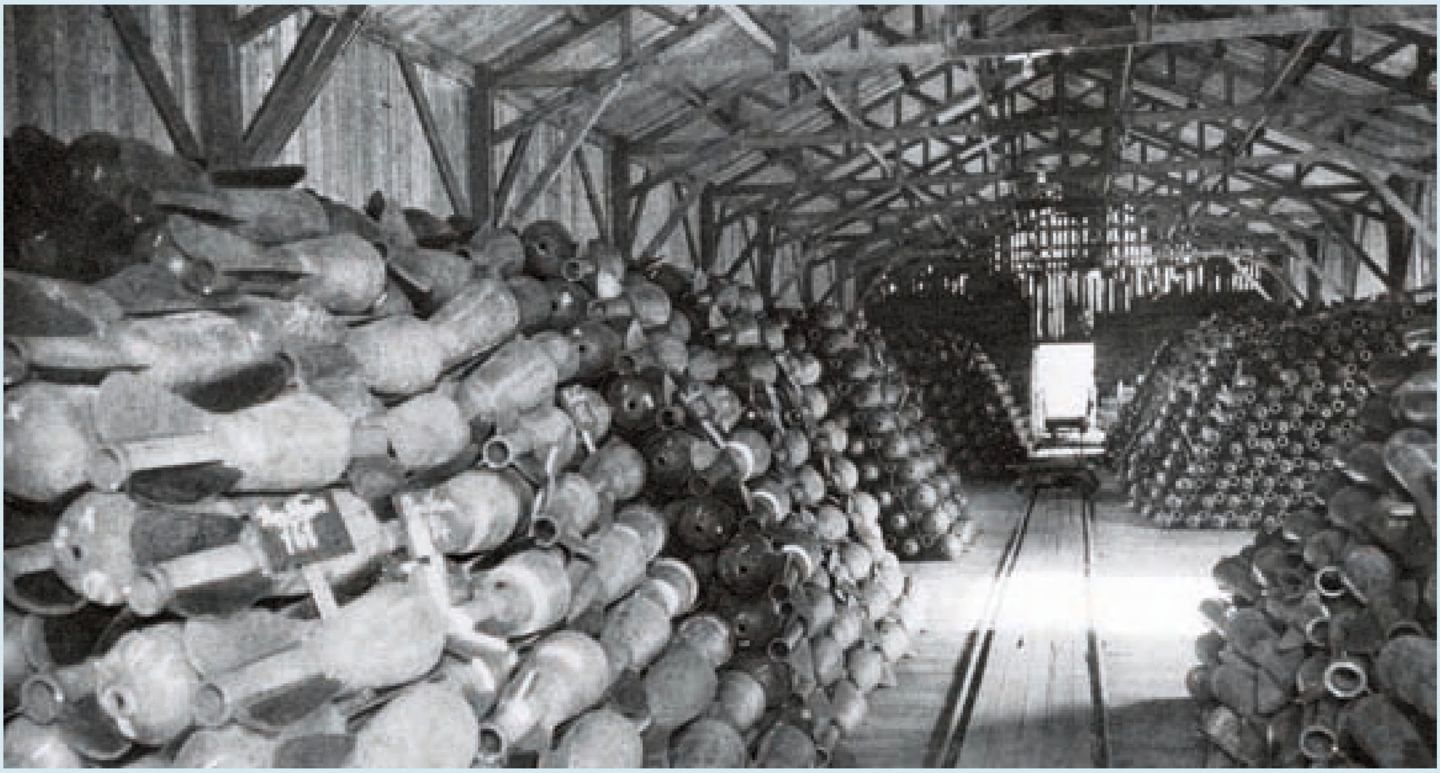
Thousands of bombs and grenades...

Nobody knows exactly how much ammunition has been dumped at Paardenmarkt Bank. Most estimates are in the 35,000 tonne range. This is probably for the most part unused German ammunition, usually packed in (wooden) crates. So far it has been generally assumed that about one third of the dumped ammunition consists of chemical shells. However, there are indications suggesting that this share may be much bigger (see box).

A common misconception is that the majority of chemical shells contain mustard gas. Mustard gas (also called Yperite after the Third Battle of Ypres in 1917, where it was used for the first time) is only one of many chemical warfare agents from WWI. Other commonly used chemical warfare agents included chloropicrin, phosgene, diphosgene and (extremely toxic) arsenic compounds (so-called '*Clark*')(see illustration on p.56). The ratio between these substances is unknown, but in all probability mustard gas shells do not exceed one third of the chemical munition on Paardenmarkt Bank.



The pentagonal area of prohibition (in red) of the ammunition dump site on Paardenmarkt Bank. Right: bathymetric chart of the area on the basis of soundings taken by the Flemish administration in 1996. Depth in metres MLLWS (Mean Lowest Low Water level at Spring tide). The circle at the top-right corner shows the location of the Zeebrugge Oost dredgings dump site)



An ammunition depot for storage of finned bombs for Van Deuren mortars. These weapons proved to be effective against German U-boats ("N'Oublions Jamais" series of photos published by the army's photographic service after the war)

The dumping of ammunition at sea after WWI (ORO Nieuws Knokke-Heist)

There is still a great deal of uncertainty about the dumping operation at Paardenmarkt Bank. No reports or hard evidence has been available so far. The Belgian military archives (from the interwar period), which were located in Moscow until recently, may shed some light on the matter. However, the files of the *Commission Centrale de Récuperation* included therein are not just very voluminous, the Soviets also created a lot of chaos in them. The perusal of these reports will take a lot of time. However, several documents that may provide new information have recently been found in the archives of the Marine Affairs Administration.

Large quantities of ammunition were left behind, often in railway stations, at the end of WWI. In 1919 the army's 'recuperation service' collected these war materials (German as well as British and Belgian ammunition) and stored them in ammunition depots across Belgium. Conventional (i.e. non-chemical) shells did not pose a problem; they could be set off in fields far away from inhabited areas in a controlled manner. At the same time, attempts were made to dismantle the ammunition; German prisoners of war were often used to perform this task. This was a very slow and hazardous process, in part due to an acute shortage of trained personnel. Meanwhile, there continued to be many casualties among the civilian population, mainly due to theft of iron and copper, and sabotage.

The chemical shells were a special case. The shells, estimated at hundreds of thousands and often made in Germany, could not be set off just like that, as the probability of release of highly toxic substances was too high. Burying them was not an option either because this was too risky in the long run. Dumping them at sea was initially considered too dangerous on account of the required transport, often through densely populated areas, and the risks of transshipment. However, the situation gradually became intolerable and the then Defence Minister Fulgence Masson opted for dumping at sea after all. Yet the Belgian navy did not have any suitable vessels at its disposal. The Marine Affairs Administration therefore looked for usable transport vessels.

But where should they take the ammunition to? It seemed ideal to dump it in the deep waters of the Atlantic Ocean, but this was a long way off and therefore expensive. Furthermore, this would result in a temporary accumulation of chemical shells on the quay. It seemed a better idea to dump the shells on a sandbank at a short distance from the coast, preferably a ***"banc absorbant"*** (an absorbing sandbank), and the Marine Affairs Administration shared this view. At such a site, they reasoned, the shells would quickly sink and be buried in the silt. A batch of non-chemical shells of the Belgian army (stored in the central depot or *Grand Parc de Campagne*) had already been dumped on sandbanks off Gravelines. Eventually, Mr Urbain, head of the Hydrography department of the Marine Affairs Administration, designated Paardenmarkt Bank as the ideal site. The dumping operation could be carried out with relatively small vessels. This meant that no large quantities of toxic ammunition had to be stacked on the quay in the port of Zeebrugge.

Problems soon followed, however. By August 1919, the workers had realised the danger of transporting such a cargo and therefore demanded exorbitant wages. This threatened to delay the operation and the ministers wanted to prevent this, as the country had been struck by various large explosions the previous months. Entire trainloads of ammunition had exploded and people were frightened.

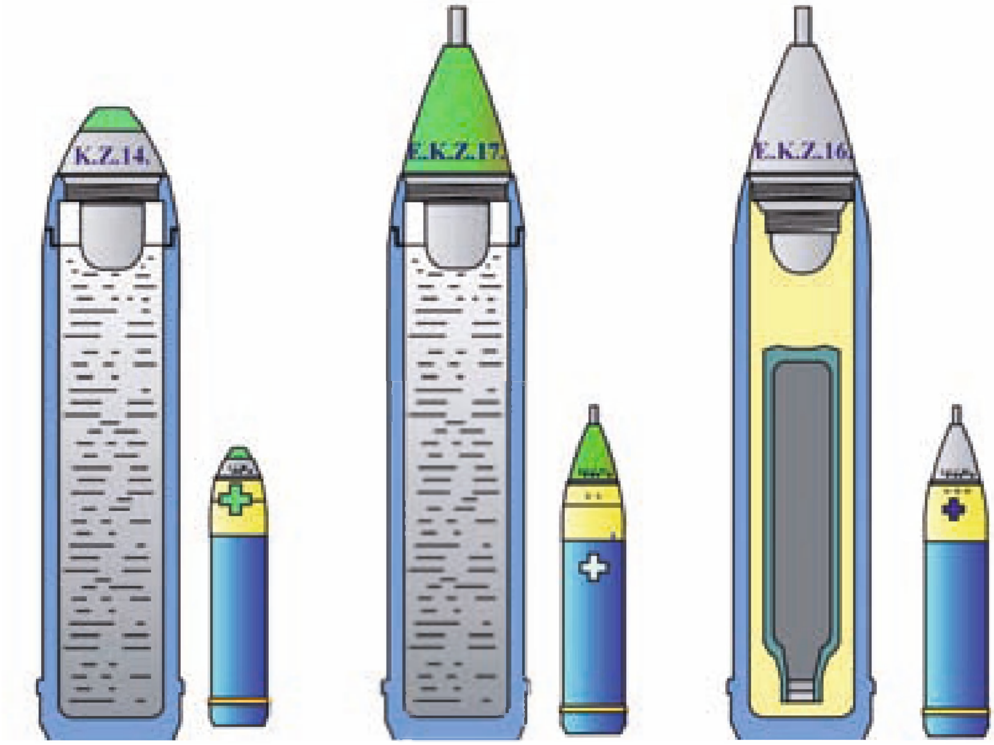
An image of the seabed off the Belgian coast (EOS N° 6, 2013, 'Duizend bommen en granaten')

The dumping operation on Paardenmarkt Bank began on 22 October 1919. It was carried out by the Marine Affairs Administration in close cooperation with the Ministry of Defence. The operation progressed steadily without many incidents, except for a small boat whose cargo exploded at just five metres from the quay wall on 18 December. The vessel sank and one of the persons on board was killed. On 17 January 1920 it was announced that the operation was finished, much to the relief of the Marine Affairs Administration. Because many unexploded shells turned up afterwards, new boat trips were made to Paardenmarkt Bank from the end of March 1920 onwards.

To this day the exact quantity of dumped ammunition remains a matter for conjecture. The generally accepted estimate of 35,000 tonnes is based on a (non-contemporary) testimony. It was written down by the Navy in 1971 and states that a shipload of ammunition (approx 300 tonnes) was dumped every (working) day for 6 months. However, recently found documents of the Marine Affairs Administration do not mention a word about this. The exact quantities mentioned in correspondence are very vague as well. Parliamentary reports and newspapers from 1919 and 1920 speak of 50,000 to 100,000 tonnes of abandoned war materials (in some cases up to 200,000 tonnes). How much of this ended up in the sea is unclear. It is therefore possible that (much) more ammunition was dumped.

It is also uncertain what share of this ammunition consists of chemical shells. The common estimate of one third chemical shells (and two thirds non-chemical ammunition) is based on production figures from WWI. But although chemical shells made up between a quarter and a third of the total amount of artillery ammunition produced in the last months of the war, it is likely that the ammunition was dumped selectively on Paardenmarkt Bank. This is confirmed by documents from the Marine Affairs Administration archives which expressly state that only chemical shells were dumped. If this is correct, the amount of chemical munition would be considerably larger.

However, a final remark as to the dumping operation is worthwhile. Newspaper reports from 1919 refer to previous dumping operation(s) carried out by the British admiralty in mid-1919. The ammunition in question is reported to have come from the British zone of the Yser front. The minutes of the parliamentary debates of 5 March 1919 refer to a report by the British authorities according to which over 16,000 tonnes of ammunition coming from some 20 stations was collected on 6 February 1919 and subsequently transferred to 1,600 goods wagons. Research in the British Public Office Records at Kew in 2002 indicates that these war materials were probably dumped in British waters. The quantity and the exact types of ammunition that were dumped are unknown.



GREEN CROSS
(chloropicrin, phosgene)

YELLOW CROSS
(mustard gas)

BLUE CROSS
(Clark)

Sectional view of German chemical shells from WWI. The shells were marked with a blue, green or yellow cross according to the chemical filling...

Belgian soldiers of the third army division at an observation post in 1918. They are carrying a newly designed gas mask which protects both the lungs and the eyes.
("N'Oublions Jamais" series of photos published by the army's photographic service after the war)

The word poison gas is misleading in this case: most chemical agents are liquid or solid, and only exceptionally volatile. This is also true of mustard gas, which is a viscous liquid in pure form at normal temperatures. However, most chemical warfare agents will slowly evaporate when used and form the well-known 'gas cloud' that lingered in the trenches.

On average, the chemical filling is about one tenth of the total weight of a chemical shell, the remainder being for the most part the ammunition body. If we accept the conservative estimate of 35,000 tonnes of ammunition dumped on Paardenmarkt Bank, this would mean that at least 1,200 tonnes or possibly even 3,500 tonnes are chemical warfare agents. The dispersing explosives (e.g. TNT) are often highly toxic as well. They form a very small part of the chemical shell (typically a few hundred grams), but they can make up as much as one tenth of the total weight of the shell in case of conventional ammunition.

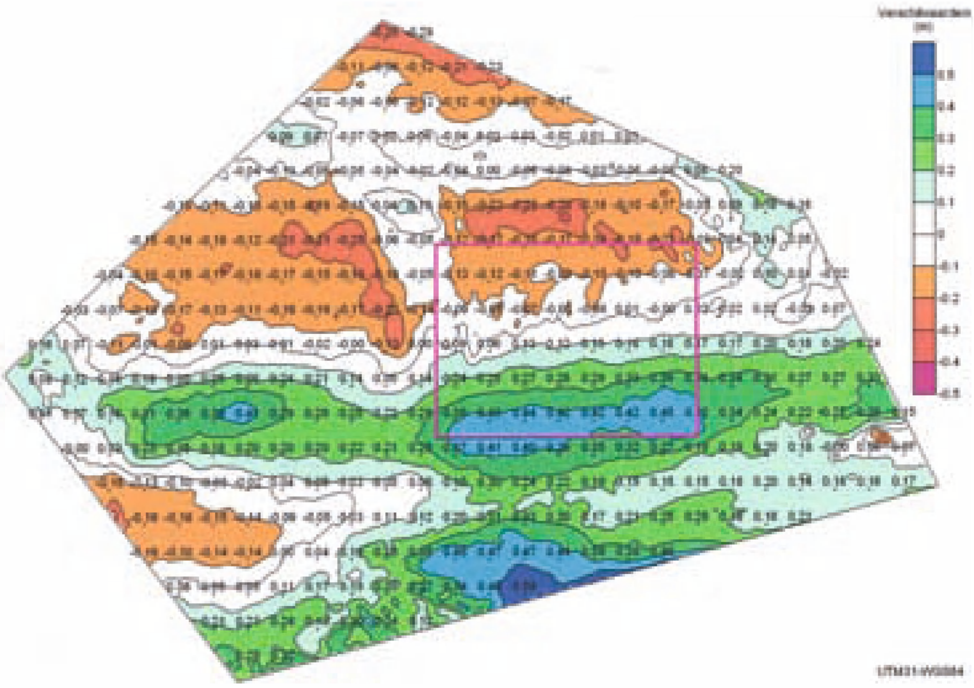
On or in the seabed

The ammunition found during the 1972 diving operations was located on or just below the seabed. These shells have been largely covered by a layer of sediment by now, as the current pattern has radically changed since the extension of the port of Zeebrugge in the late 1970s and early 1980s. This has resulted in significant sedimentation in the ammunition dump area. The proximity of the Zeebrugge Oost dredgings dump site may also have played a role. The amount of sediment deposited is largest in the southwest (up to 4 m) and decreases northwards. In addition, the new current pattern has created an erosion area northwest of the dump site. This erosion area seems to move slowly towards the east.

Recent topographical studies seem to indicate a stagnation in the sedimentation process. Between 1996 and 2003 the ammunition dump site was still largely subject to a sediment accumulation of 10 to 60 cm, about 850,000 m³ in total. Virtually no erosion occurred in this period, except in two small areas in the far southeast and northeast. Between 2003 and 2011, however, almost the entire dump site was subject to erosion, approx 612,000 m³ in total. Erosion was greatest in the central and the northeastern part (up to 60 cm); only the part of the ammunition dump site closest to land was subject to a small sediment accumulation (up to 20 cm) in this period. The net result over the 1996-2011 period is therefore a slight sediment increase in the southern part and slight erosion in the northern part (see map).

So far it is unclear what the evolution of the site will be over the coming years. It is possible that the ammunition dump site has achieved a new balance after the construction of the moles. In this case, the minor volumetric fluctuations of the last few years can be interpreted as periodical fluctuations around an equilibrium point. Seasonal factors may play a part in this process as well. On the other hand, it is possible that the erosion in the northern part and the sedimentation in the southern part will continue.

The current water depth of the ammunition dump site varies between 1 m and 5 m MLLWS (Mean Lowest Low Water level at Spring tide i.e. the zero line on nautical charts). Recent magnetic measurements indicate that most shells are covered by at least a couple of metres of sediment. The exact depth at which the shells are buried is difficult to determine with certainty, but according to provisional rough estimates they are buried at a depth of 2 to 6 metres below the seabed. The highest concentration of shells appears to be in the central part of the ammunition dump site. In 2012 sophisticated magnetic equipment was dragged just above the seabed to conduct a large-scale measurement campaign at the ammunition dump site. This should allow to sketch a highly detailed picture of the buried ammunition. This way, researchers hope to distinguish individual shells from clusters of ammunition.

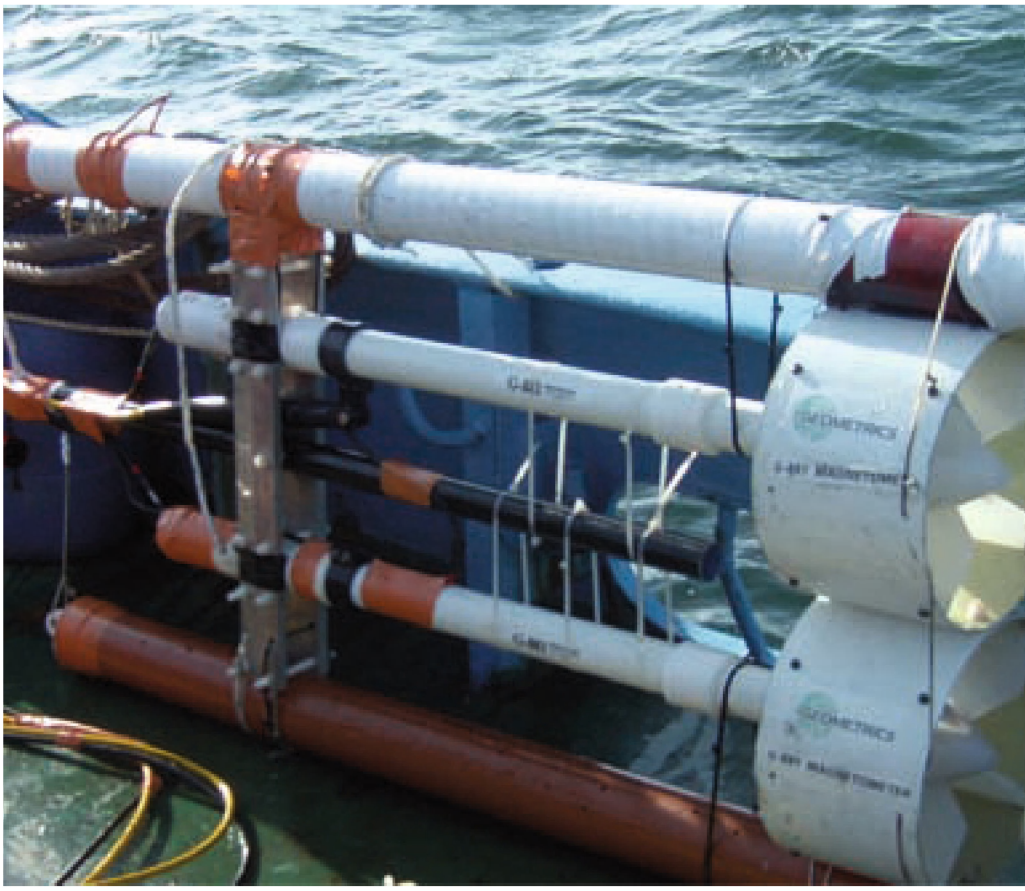


Topographical evolution of the ammunition dump site between 1996 and 2011. As can be clearly seen in the image, the southern part is characterised by slight sedimentation (blue and green areas) while slight erosion occurs in the northern part (orange and red areas). The red rectangle indicates the zone with the highest concentration of ammunition (Magelas)

Slow corrosion

A number of shells were brought to the surface in 1972. The condition of the shells was "remarkably good" according to the reports written at the time. This may be explained by the occurrence of natural gas (methane) in the seabed, caused by the bacterial decomposition of organic matter. This creates a low-oxygen environment, which can slow down corrosion to a considerable extent. No ammunition has been brought to the surface since 1972, however, so the current state of the shells is unknown. Nevertheless, it seems plausible that the ammunition has not corroded very much at this moment.

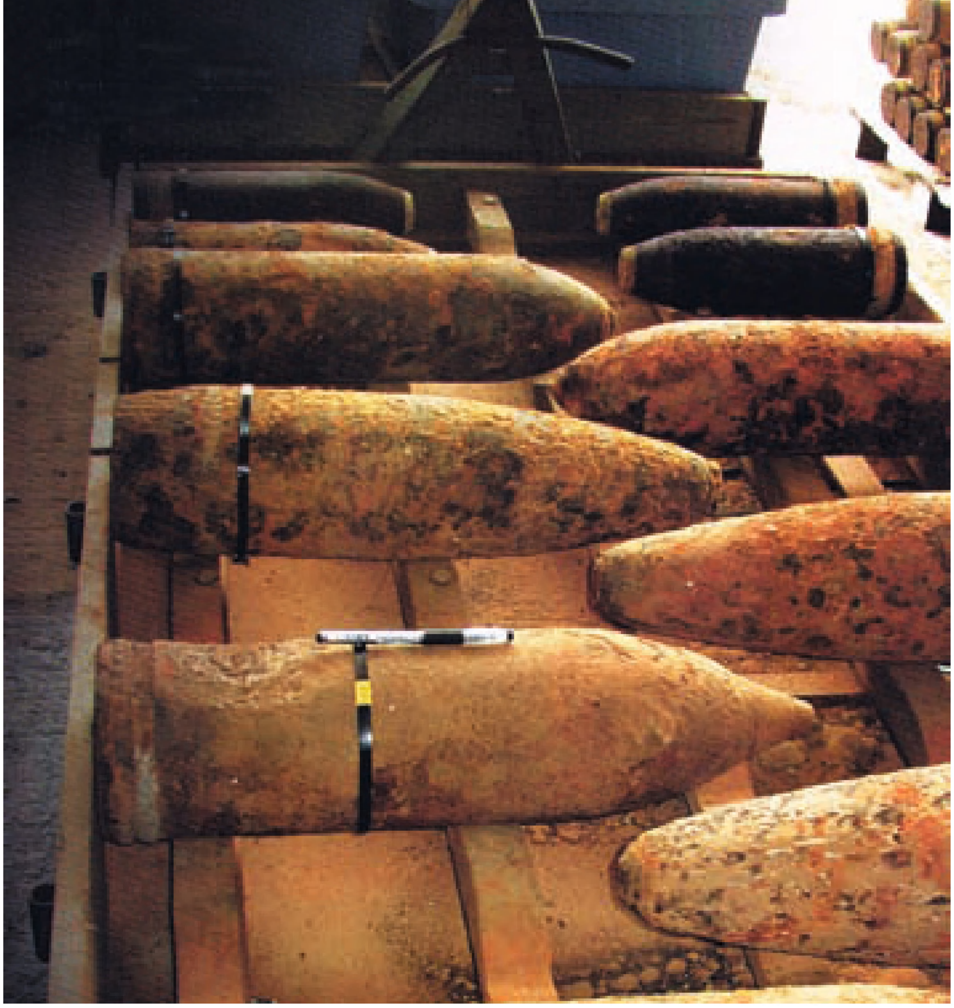
Since the 1990s, sediment and water samples taken at numerous locations in the dump area have been examined on a regular basis (every 2 years on average). The samples are analysed for the presence of mustard gas, Clark, phosgene and their (equally toxic) degradation products as well as explosives (in particular TNT) and heavy metals. So far, only one sediment sample showed traces of contamination (a low concentration of mustard gas). Subsequent samples taken at the same location did not reveal any traces of mustard gas. However, prudence is called for when conclusions are drawn from these sampling campaigns. On the one hand, it is possible that there is no contamination of the seabed (yet) (the samples were taken at a depth of up to 50 cm). On the other, it is equally possible that the used detection limits were too high to detect extremely low toxic concentrations.



Magnetometers that are used to image the ammunition below the seabed (Tine Missiaen)

Moreover, we should keep in mind that even slow corrosion cannot prevent the shells from leaking in the long run. When this will happen is unclear.

According to calculations, it could take hundreds or even thousands of years for all ammunition to corrode.



Shells from the First World War await identification in the West Flemish village of Poelkapelle (EOS N° 6, 2013, 'Duizend bommen en granaten')

What if the shells start to leak?

Corrosion of the shells will cause the chemical agents to be released only very slowly, so that the chemicals are very likely to get diluted. High concentrations are therefore only suspected in the immediate vicinity of the shell. Due to the large degree of dilution and the relatively quick hydrolysis (i.e. the decomposition of a chemical compound by reaction with water), most chemical agents will probably not pose much of a threat to the marine environment. There are two exceptions: Clark and mustard gas, which are both extremely toxic and break down only very slowly. Furthermore, their degradation products are often equally toxic as well.

Arsenic compounds (such as Clark) easily adsorb onto sediment particles, so that they may pose a threat to the animals and plants living on and in the seabed. Recent studies state that the release of Clark from a buried shell will probably lead to contamination of the sediment within a radius ranging from ± 0.5 m (after 10 years) to ± 1.5 m (after 100 years). The possibility of acute contamination of the water column is slim, but sediment pollution can occur over much greater distances due to soil erosion.

Mustard gas is characterised by extremely slow hydrolysis and can therefore remain active for a long period of time, up to several decades or more. Studies indicate that the mustard gas will, to a large extent, remain inside the remnants of ammunition after the shell has corroded. This means the volume of contaminated sediment around a leaking shell will remain relatively small. Nevertheless, lumps of mustard gas can be released as a result of mechanical disruption (e.g. caused by anchors or fishing nets). Mustard gas seems to pose the biggest threat when it comes into direct contact with organisms.

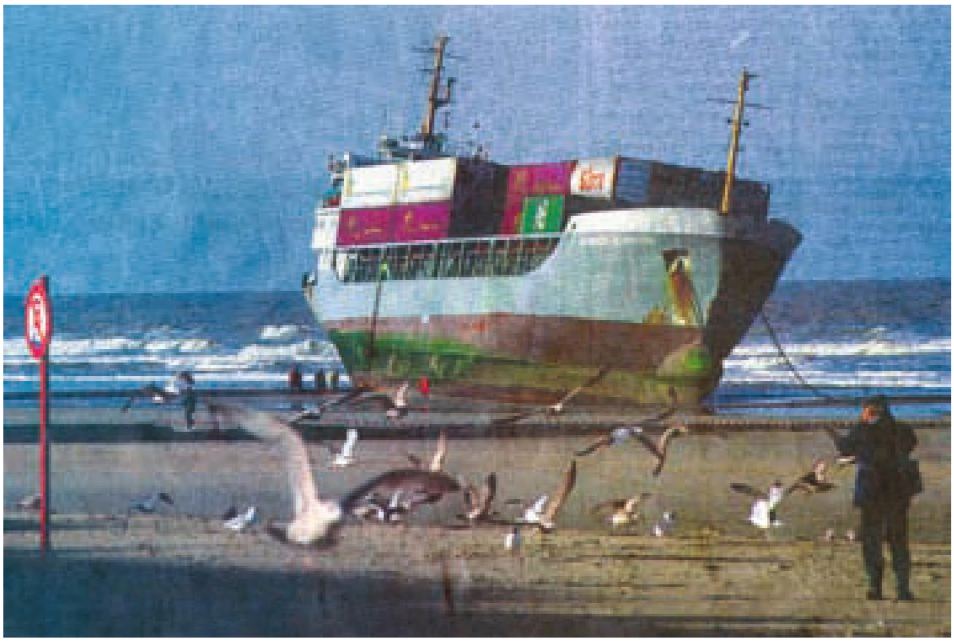
The presence of large quantities of *TNT* and *heavy metals* (which do not break down) may constitute an additional environmental hazard. Because of the slow corrosion and the large degree of dilution, their concentration will in all probability be relatively low, although peak concentrations near the shell cannot be excluded.

Shipping disasters: a real threat to the dump site?

Thanks to the present sediment cover it is unlikely that shells will be washed ashore. Currently, the biggest threat seems to come from accidents, e.g. shipping disasters, as the ammunition dump site is located near one of the busiest ports of northwestern Europe, within a stone's throw of the principal shipping routes and numerous pipelines, and close to one of the largest LNG terminals.

On the face of it, it seems very unlikely that a large ship will run aground on Paardenmarkt Bank. Ships with a relatively deep draught (such as tankers and container ships) are likely to get stranded before they reach the ammunition dump site. Yet several ships have run ashore on the Belgian coast in stormy weather over the past decades. The most recent accident took place in November 2001, when a German container ship was stranded on the beach of Blankenberge (see image).

The possibility of ammunition exploding in case of a mechanical impact is small (≤ 10%). However, there is a real risk that the ammunition will (continue to) burst open and that the contents will be released. As

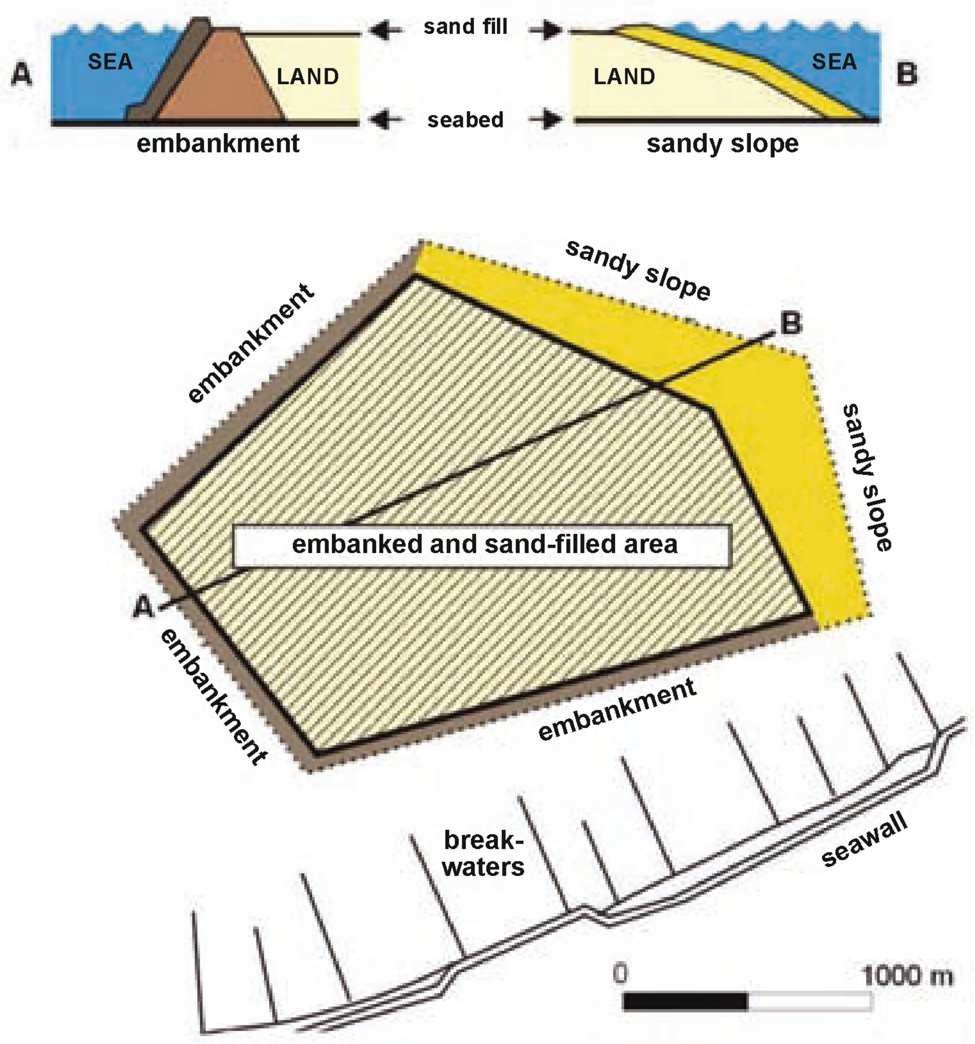


The German container ship Heinrich Behrmann was stranded on the beach of Blankenberge in November 2001. There is a real danger that such an accident could occur near Paardenmarkt Bank (VLIZ) the ammunition comes from stocks, there is sufficient reason to assume that the detonator was deactivated. However, there is a possibility that relatively intact shells filled with (active) explosives will react under the pressure, which could result in an explosion. The current sediment cover in the ammunition dump site forms a natural protection, however, and will certainly limit a possible impact. Nevertheless, the North Sea Disaster Contingency Plan takes into account the special character of Paardenmarkt Bank.

Contaminated fish?

Arsenic compounds could well be the main source of contamination of fish directly linked to the ammunition dump site. Especially fish that feed on organisms living in or on the seabed (so-called *benthos*) are at risk from increased arsenic concentrations. The principal commercial fish species occurring in the Belgian littoral zone include flatfish (plaice, flounder, sole), brown shrimp and, to a lesser extent, whiting and cod. Marine benthic life in the eastern Belgian littoral zone has deteriorated partly as a result of chemical pollution of the Scheldt estuary.

Commercial fishing in the immediate vicinity of the ammunition dump site (fishing is still banned on the site itself) is for the most part limited to shrimping, usually by means of small boats, while larger vessels operate further offshore. In view of the recent sedimentation, the (supposedly) good condition of the shells and the relatively small contamination radius, the risk of contamination of fish or shrimp for human consumption seems to be minimal at present.



Possible civil engineering solution for covering the ammunition dump site with an artificial island. Three sides of the island are formed by an embankment, the other two sides are sandy slopes (Tine Missiaen)

However, contamination is still possible in the future. Vigilance and regular inspections are therefore required.

Salvage does not seem a good idea

Salvaging the ammunition seems technically feasible, but it is a very costly and hazardous undertaking involving considerable risks both to personnel and the environment. The risk of uncontrolled quantities of harmful substances being released into the environment during the salvage operation is very high. Moreover, such an operation also requires specially adapted transport and storage facilities.

One of the principal concerns remains the dismantlement of the salvaged shells. The destruction of such a large quantity of ammunition requires a very extensive dismantling capacity. The current capacity of the dismantlement facility for chemical shells in Poelkapelle is very limited. Over 2600 chemical shells are currently awaiting dismantlement. Shells are still found in fields on a daily basis. Unless there is an acute risk, salvage of the ammunition therefore does not seem to be the best option. Theoretically speaking, it nonetheless remains the only option to resolve the matter once and for all.

Local containment

If there were indications that the ammunition would surface, e.g. due to erosion of (part of) the dump site, partial or complete containment of the site could be considered. In 2009 Ghent University conducted a feasibility study which revealed the three best options: (1) Locally depositing soil on the eroding area. This option has the major advantage of being relatively cheap, but it is not very sustainable since it requires regular maintenance. (2) Constructing a freestanding breakwater on the seaward side. This minimises the risk of a shipping disaster and is conducive to sedimentation of the dump site. A major disadvantage is that the exact behaviour of this sedimentation process is hard to predict; it is possible that the area between the dump site and the coast inadvertently silts up completely. (3) Creating an artificial island. This is a sustainable solution, but it is also very expensive.

The construction of an island does provide important opportunities such as nesting sites for terns, gulls and plovers as well as haul-out sites for seals. The current tern and gull populations in Zeebrugge are doomed to disappear as a result of the further development of the port, so a tern island on the dump site would ensure the survival of these birds in Belgium.

The activity of a dredged up shell is checked. (EOS N° 6, 2013, 'Duizend bommen en granaten')

Paardenmarkt Bank is one of the world's most studied chemical munition dump sites at sea. Scientists abroad are envious of this, and rightly so. But experience has taught that a transparent policy and openness to the public are also of crucial importance. This is the only way to remove the many uncertainties and doubts as to this matter and avoid exaggerated public panic.

However, we must bear in mind that locally depositing soil on the dump site or its conversion into an island will not solve the problem of leaking ammunition as such. Additional inspections will therefore still be needed.

Frequent monitoring is necessary

At the moment there seem to be no indications of immediate danger. Consequently, the best option is to let the ammunition dump site be. In view of the short distance to the coast and the shallow water depth, frequent monitoring of the area remains highly important. Measurement campaigns by means of multibeam echosounder (and if need be side-scan sonar) regularly take place to monitor the evolution of the seabed. This makes it possible to keep track of the erosion and accumulation process and detect objects on the sea floor.

However, chemical monitoring on the basis of regular sampling campaigns remains the most important method of detecting toxic contamination. This has taken place twice a year on average since the mid-1990s. Advanced analysis techniques are required to measure the expected low toxic concentrations during these operations. A new protocol has recently been developed abroad with regard to sample preparation, quantitative analysis and validation for detecting chemical warfare agents in and around ammunition dump sites at sea. Studies are under way to determine how this protocol can be optimally applied to Paardenmarkt Bank.

Despite the conducted (and ongoing) research, a lot of factors are still unknown. For instance, virtually nothing is known about the state of the ammunition. It is therefore advisable to bring several shells to the surface. A thorough analysis of these shells combined with a numerical modelling of the corrosion should eventually provide a better insight into the state of the corrosion process and the consequences thereof in terms of the release of chemical warfare agents.

At present, very little is known about the spread of toxic substances in the water column as well. Detailed hydrodynamic research by means of numerical experiments is therefore required to model the movement of the released toxic substances under different circumstances (wind and wave characteristics, current, tide ...).

A thorough long-term strategy for the dump site is of vital importance, not just in order to manage the monitoring operations and achieve a fundamental understanding, but also to guarantee good communication. International studies such as the European MERCW (Modelling of Environmental Risks related to sea-dumped Chemical Weapons) project have shown that a manageable database and user-friendly visualisation play an important part. These make it possible to gain a clear insight into factors such as the depth at which the ammunition is located, changes in the terrain, the exact position of the ammunition, toxic concentration in sediment and water, and even possible risk scenarios. Such a database has not been developed yet for the Paardenmarkt site. This is problematic since such a database is essential for optimum monitoring and efficient future research. It allows us to tackle the problem in the best possible way, now and in the future.

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