15. The destruction of old chemical munitions in Belgium

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I. Chemical warfare in Belgium in World War I

During World War I the northernmost part of the front line cut through the Belgian province of West Vlaanderen, running roughly from the coastal town of Nieuwpoort on the Yzer estuary over Diksmuide and Ypres to the French border.[1] Both ends of the front line were alternately occupied by British and French troops, with Belgian forces holding the centre. In February 1918 the area controlled by Belgian troops extended to the North Sea, and by June Belgian forces held most of the Ypres salient. The front was relatively static until the final series of Allied offensives late in 1918. After the First Battle of Ypres (autumn 1914), which frustrated German hopes of capturing the French Channel ports, the Belgian front remained calm although interrupted by some violent fighting, particularly in the Ypres salient (e.g., the Second Battle of Ypres in the spring of 1915, the Third Battle of Ypres in the summer of 1917 and the Allied breakout in 1918). In addition, Belgium assisted Britain and France in their major offensives in France. That assistance consisted of limited actions, such as raids or artillery duels, to occupy German troops.[2] However, the flooding of the Yzer River to halt the German advance in 1914 meant that the area was not suitable for offensive operations.

The relative quiet of the battlefront and the resulting hope of surprise probably explain why experiments with new toxic substances were carried out in Flanders. The Ypres salient was one of few sectors where the prevailing winds were not south-westerly. The presence elsewhere of disadvantageous winds from the south-west contributed to Germany's adoption of the use of shells for its chemical attacks, while the Allies, notably Britain, employed cloud gas attacks until the final days of the war. Appendix 15A summarizes the documented chemical warfare operations which took place on Belgian territory.

Modern chemical warfare is regarded as having begun on 22 April 1915. On that date German troops opened approximately 6000 cylinders along a 7-km line opposite the French position and released 150–168 tonnes of chlorine gas. Tear-gas (T) shells were also fired into the cloud and at the northern flank, the boundary between French and Belgian troops. Between 24 April and 24 May Germany launched eight more chlorine attacks. However, chemical warfare had not been assimilated into military doctrine, and German troops

[1] Belgium is a multilingual country, and the relative importance of Flemish and French has shifted dramatically in the past, resulting in various spellings for names of places. The spellings used here are those of the current official language for the respective places unless they have an English name. In 1900–30 French was the dominant language for all administrative and legal purposes. This is reflected in names of governmental bodies and military units. The names used in official documents are also retained.

[2] Lheureux, V. (2nd Lt.), 'L'utilisation des gaz de combat sur le front belge pendant la guerre 1914–1918' [Use of gas on the Belgian front in the 1914–18 war], and its annexes, Travail de fin d'études présenté pour l'obtention du titre de licencié en Sciences Sociales et Militaires, Ecole Royale Militaire, 126e Promotion Toutes Armes, 1989–90 [Dissertation submitted to obtain the degree of master in social and military sciences, Royal Military Academy, 126th Promotion All Arms, 1989–90], p. 46.

failed to exploit their strategic surprise. Chemical weapon attacks in following weeks were fundamentally different as they supported local offensives and thus served tactical purposes. In each case the amount of gas released was much smaller than that employed on 22 April, and crude individual protection against gas enabled Allied soldiers to hold the lines.

Prior to the April 1915 use of a chlorine cloud, gas shells filled with T-stoff (xylyl bromide or benzyl bromide) or a mixture of T-stoff and B-stoff (bromoacetone) had been employed. In addition, as early as 14 February 1915 (i.e., approximately the same period as CW trials on the Eastern front) two soldiers of the Belgian 6th Division had reported ill after a T-shell attack.[3] In March 1915 French troops at Nieuwpoort were shelled with a mixture of T- and B-stoff (T-stoff alone had proved unsatisfactory). In response to the British capture of Hill 60 (approximately 5 km south-east of Ypres), German artillery counter-attacked with T-shells on 18 April and the following days.[4] In the hours before the chlorine attack on 22 April the 45th Algerian Division experienced heavy shelling with high explosive (HE) and T-stoff.

Such attacks continued throughout the Second Battle of Ypres.[5] Although Germany overestimated the impact of T-shells, on 24 April their persistent nature appears to have been exploited for the first time for tactical purposes. Near Lizerne (approximately 10 km north of Ypres) German troops fired 1200 rounds in a wall of gas (Gaswand) behind Belgian lines to prevent reinforcements from reaching the front. The park of Boezinge Castle, where Allied troops were concentrated, was attacked in a similar manner.[6]

In 1915 only two additional gas attacks are known to have occurred in Belgium after the Second Battle of Ypres. In the first of these T-shells were used against a Belgian unit on 16 August; in the second attack, near Ypres on 19 December, a phosgene cloud was used for the first time. This marked the 'return' of German gas operations from the Eastern front. In 1916 the first British cloud gas attacks from trenches took place in Belgium, but gas was used infrequently in Flanders in 1916.

However, 1917 marked a turning point for three reasons. First, after 23 April the number of gas attacks in Belgium increased significantly. Shells and mortar bombs began to be used instead of cylinders, and this contributed to the assimilation of gas tactics into the planning of operations. Second, during the night of 12–13 July German forces used mustard gas for the first time when 50 000 shells were fired into the Ypres salient. Two days earlier, at Nieuwpoort, Germany had used blue cross (diphenylchloroarsine) shells for the first time in an attempt to counteract the measures being employed to protect troops against gas.[7] Third, with shells in general use the flooded areas, which had previously

[3] Decuyper, Dr, *Journal de Campagne*, Brugs Genootschap voor Geschiedenis, 1968 [Diary of the campaign, Bruges Society for History], in Baccarne, R. and Steen, J., *Boezinge 1914–1918: Gasaanval 2° Slag om Ieper* [Boezinge 1914–18: gas attack at the Second Battle of Ypres] (Uitgegeven onder de auspiciën van de N. V. Bank van Roeselare en West Vlaanderen [Published under the auspices of the N. V. Bank van Roeselare en West Vlaanderen], 1979), p. 135 (in Dutch).

[4] Foulkes, C. H., *'Gas!': The Story of the Special Brigade* (William Blackwood & Sons: Edinburgh and London, 1936, 2nd reprint), p. 34.

[5] Haber, L. F., *The Poisonous Cloud: Chemical Warfare in the First World War* (Clarendon Press: Oxford, 1986), pp. 25, 33–34. See also the detailed chronicle by Baccarne and Steen (note 3), pp. 128–88.

[6] Baccarne and Steen (note 3), p. 171.

[7] For a discussion of the cross codes, see the subsection 'Colour coding using cross codes' in section II of chapter 6 in this volume.

shielded Belgian troops from cloud gas attacks, no longer functioned as a protective barrier. The use of CW was now common on the front lines. This led to the little-known Belgian retaliatory gas shell attacks in the autumn and to the general use of gas shells for retaliation, harassment and counter-battery fire throughout 1918.[8]

Belgium was occupied for most of the war and was unable to produce chemical munitions indigenously; instead, shells were purchased primarily from France. The shells that were purchased included: hydrogen cyanide (shell no. 4), phosgene (shell no. 5) and—for the final offensive in 1918—mustard gas (shell no. 20). Belgium also bought chloropicrin shells (NC) from Britain. Although it is not known how they were procured, Belgium obviously possessed large quantities of German T-stoff shells since field manuals which refer to captured munitions extensively detail their use. The Belgian forces fired approximately 260 000 chemical rounds (25 per cent of all shells), and 55 per cent of these rounds were consumed in the period from the start of the final offensive on 28 September until the end of the war.[9]

There were four phases of chemical warfare in Flanders. In the first phase, from April 1915 until December 1915, cloud gas attacks dominated, and there was some use of T-shells. Nieuwpoort and the Ypres salient were the main combat areas. Waterways or flooded fields separated the battlelines in the central sector, and this probably explains the absence of cylinder attacks there.

In the second phase, December 1915–March 1917, there were few gas operation on the Belgian front. Only approximately 10 such operations are on record, and the majority of these were carried out in the Ypres salient. In this phase new chemical agents such as phosgene were introduced, the first British counter-attacks took place and the use of cylinders was gradually replaced by the use of shells.

The third phase, April 1917–September 1918, was marked by a dramatic shift in the nature of chemical warfare activities. Gas tactics had been assimilated into the military strategies of the major belligerents to varying degrees and chemical agents began to be used liberally for various purposes. In addition, new compounds, such as mustard gas, were introduced which changed the nature and perception of chemical warfare. In the Third Battle of Ypres large quantities of artillery shells, many of which contained gas, were used by all participants.

In Flanders two particular events influenced developments. On 23 April 1917, at Nieuwpoort, an unexpected wind diverted a massive chlorine cloud which German forces had released against French troops and which drifted across the entire length of the front held by Belgian forces. Belgian commanders and troops, who had previously not been concerned about gas warfare because of the relative safety offered by the flooded areas and waterways, were

[8] Only few people, including military and local historians, are aware of Belgian gas operations and defence measures. There are three main reasons for this. First, most literature on gas operations is of British, French, German or US origin and deals with the activities of each country's own troops, giving the erroneous impression that the sector held by Belgian troops was hardly attacked with CW. Second, the literature focuses mainly on operations by special troops or special events. By the time Belgian troops began using gas, chemical artillery bombardments had become routine and thus hardly worth mentioning. Third, Belgian official histories studiously avoided direct references to Allied chemical attacks and retaliation, and no mention was made of Belgian involvement. The only known analysis based on original documents is the unpublished dissertation by Lheureux (note 2).

[9] Lheureux (note 2), pp. 92–102, and documents reproduced in its appendices V and X.

now forced to organize gas defence and to conduct training. Three months later, during the Third Battle of Ypres and after several German gas shell attacks against Belgian positions, the Belgian High Command took the decision to stock chemical munitions. However, for reasons which are not known the first Belgian use of gas did not take place until the end of October or early November following several weeks of gas attacks by German forces.[10]

From April 1917 the entire front in Flanders was the site of general chemical warfare. Mustard gas could be used effectively in Flanders because it was less affected by the 'microclimate'. (The inundated land was no longer a factor that prevented widespread use of cloud attacks.) Its introduction directly affected the Belgian approach to CW. Nevertheless, offensive operations were only possible south of Diksmuide. When Belgian troops began extending their lines towards the Ypres salient in 1918 greater involvement in gas operations became inevitable. However, until the end of the third phase and even during the German spring offensive of March 1918, official Belgian policy was one of in-kind retaliation only.

At the beginning of the fourth phase, September 1918 to the armistice, the Belgian High Command issued directives for the use of gas as a component of offensive operations. The availability of yperite shells (to be supplied by the French) was even a precondition for Belgian participation in the final offensive, which began at the end of September 1918. In this final phase of chemical warfare in Flanders the Belgian, British and French forces used gas shells extensively in the preparatory attack stages, targeting German artillery positions in particular.[11] In addition, units of the British Special Brigade supported tactical engagements with portable mortars. German forces, on the other hand, used gas as part of their defensive strategy. Civilians behind German lines had not received gas masks, and there were numerous casualties when villages were subjected to gas attacks by both sides. Gas was still being used in early November 1918, and Belgian communiqués for 2–11 November reported 'intense activity'.

Several chemical warfare 'milestones' took place in Flanders: chlorine, phosgene, blue cross and mustard gas were all first used on the Belgian front, and yperite derived its name from its use in Belgium. More important perhaps than the introduction of these gases was the rapid adoption of a strategy of general and intense use of CW in West Vlaanderen which began to be practised some months before the Third Battle of Ypres. This change in strategy coincided with the first use of the vesicant yellow cross and affected both the military and civilians for the remainder of the war. In addition, improved artillery made easy targets of areas in the rear that were occupied by civilians. Belgian armed forces are estimated to have suffered 40 per cent of all war casualties and 80 per cent of all gas casualties in 1918, the latter figure represents 16 per cent of all casualties for that year.[12] The psychological effects of chemical warfare lingered long after the armistice not least because of the many accidents involving unexploded munitions and the slow and painful recovery of many of those who had been gassed.

[10] Lheureux (note 2), p. 84. Official communiqués issued in Sep. 1917 mention retaliation, but without reference to the use of gas. The first explicit mention is in the communiqué of 3–9 Nov. 1917.

[11] Lheureux (note 2), pp. 93–94.

[12] Lheureux (note 2), p. 108.

II. Early disposal of old chemical munitions

Immediately after the armistice on 11 November 1918 the removal of munitions from the former battlefields became a task of the utmost urgency. The problem was twofold. First, some 30 per cent of the ammunition fired between 1914 and 1918 failed to detonate, and unexploded munitions littered the zone where the front line had remained stagnant for four years. Second, retreating German troops had left many munition dumps. Civilians began searching for shells in order to obtain the valuable metals contained in them. Crude methods which did not distinguish between explosive and toxic munitions were used to remove the explosive so that the iron and copper in the shell casing or driving band could be sold. The weapon components which could not be sold were buried or dumped in the rivers. Inevitably, there were numerous casualties. Collecting scrap iron and copper was so lucrative that a subsidiary of a British firm, F. N. Pickett et Fils, was established to take advantage of the situation, and a number of small Belgian companies were also set up. Men, women and children collected the iron and copper for independent iron mongers (not Pickett) but for such low wages that in 1920 the authorities intervened and ended the practice.[13]

In 1920 the Service de Destruction des Munitions (SDM, service for the destruction of munitions) was created as part of the Commission Centrale de la Récupération (CCR, central commission for recovery) to deal with the munition problem in addition to its other responsibilities. Initially, the SDM had sections attached to each Provincial Service of the CCR. In West Vlaanderen the SDM was assisted by another branch of the CCR, the Service des Régions Dévastées (SRD, service of the devastated regions), which operated only in the former front-line area.[14] The principal task of the SDM was to retrieve and destroy munitions, and it operated its own destruction sites. However, manpower levels were soon drastically reduced, in part as a result of the removal of German munition dumps from the area between the front line and the border between Belgium and Germany. Some military and civil officials expressed optimism that West Vlaanderen would be completely cleared by the end of 1922. The problem was reappraised after huge German munition dumps were uncovered, and it was learned that municipal officials had not reported the existence of such dumps because they had failed to appreciate the danger to the local population.[15] The Haut Commissariat de la Côte (high commission of the coast), which was responsible for the sector between Ostend and the French border, had its own Service de la Côte (service of the coast), clearly as a matter of prestige, to collect and destroy all munitions found in the area. It answered directly to the CCR, rather than to the SDM.[16]

[13] Craenen, P. (2nd Lt.), 'Historiek van de Belgische Ontmijningsdienst' [History of the Belgian Bomb Disposal Service], Afstudeerwerk voorgelegd tot het bekomen van de titel van licentiaat in de Militaire- en Sociale Wetenschappen. Koninklijk Militaire School, 125e Promotie Alle Wapens, Brussels, 1989 [Dissertation submitted to obtain the degree of master in social and military sciences, Royal Military Academy, 125th Promotion All Arms, 1989], pp. 1–2 (in Dutch); and Baccarne, R. and Steen, J., *Poelkapelle 1914–1918* (Drukkerij-Uitgeverij Almar: Wervik, Belgium, 1968, 2nd edn), pp. 170–72 (in Dutch).

[14] Documents and literature often confuse these agencies when dealing with former front-line areas.

[15] Craenen (note 13), chapter 1.

[16] 'Rapport relatif à l'organisation et à l'activité du service à la Côte' [Report on the organization and the activities of the service of the coast], Annexe au Document no. 48818/A/2730 de la Commission Cen-

There is little information on the munition disposal activities of these organizations for 1920–22 and less for the period before World War II. Data on the disposal of CW ammunition are almost non-existent.[17] It is not clear whether the SDM systematically destroyed chemical shells at its depots, but the records which exist suggest that until at least the end of 1922 the SDM delivered toxic munitions to F. N. Pickett et Fils at Poelkapelle (see below). Most documents provide information on units operating in West Vlaanderen. Reference is made, however, to the destruction of toxic munitions which could not be transported to West Vlaanderen by the service at the Morhet depot (approximately 6 km south-west of Bastogne) in the south-eastern province of Luxembourg.[18]

The only location where the Belgian Army is known to have destroyed toxic munitions on a regular basis was Lombardsijde beach (just north of Nieuwpoort). Information about the destruction activities conducted there is detailed in a series of reports on a 2 February 1922 accident in which six labourers were killed and two injured. There are no reports about activities at the site after that date. The Service de la Côte operated the destruction site. It processed only shells which had been fired and which usually had been found in fields or during reconstruction work along the coast between Ostend and Nieuwpoort.[19] The shells were blown up, and by February 1922, 1556 tonnes of munitions had been destroyed, including 1463 tonnes of explosives (94 per cent) and 93 tonnes of gas shells (6 per cent). The rate of destruction in the four weeks prior to the accident was 11.5 tonnes of explosive and 3.5 tonnes of toxic munitions per week.[20] However, the annual rate of destruction was relatively low since most work had to be carried out during the off-season in bad weather to give the local inhabitants the opportunity to access the dunes (where high explosives were being destroyed) and the beach. Chemical shells were exploded in pits between the low- and high-water marks, and the work was limited by both the tide and the wind since destruction could occur only when the wind blew offshore.[21]

The activities of F.N. Pickett et Fils in the Houthulst–Ypres area remain obscure. The company had its headquarters in Wimereux, France, with offices in Brussels, New York, Paris and Warsaw, and the firm's letterhead describes it as Démonteurs de Munitions Toxiques et Explosives (dismantlers of toxic and explosive munitions).[22] A postal and telegraph address on another letter indicates

trale de la Récupération, Brussels, 6 Feb. 1922, Dossier MDN [Ministère de la Défense Nationale], Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

[17] The archives of the Dienst voor Historische Documentatie (CDH, Service for Historical Documentation) contain only one folder on the CCR with a number of documents relating to 1921–22. All other documents were reportedly lost following the German invasion in May 1940.

[18] Craenen (note 13), p. 5.

[19] 'Rapport relatif à l'organisation et à l'activité du service à la Côte' (note 16); and 'Rapport sur l'explosion de Lombartzyde du 2 février 1922 par le Lieutenant-Général Tollen, Président CCR' [Report on the explosion at Lombardsijde on 2 Feb. 1922 according to Lt.-Gen. Tollen, President of the CCR], Annexe au Document no. 48818/A/2730 de la Commission Centrale de la Récupération, Brussels, 6 Feb. 1922, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

[20] It was only possible to destroy explosive munitions during a few weeks each year, so work at Lombardsijde must have started soon after the armistice if the weekly rates given in the report are typical.

[21] The prevailing winds are south-westerly (i.e., onshore).

[22] 'Letter from F. N. Pickett et Fils to Lt.-Gen. Tollen, President of the CCR', Brussels, 18 May 1922, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

that a decision-making centre was located in London.[23] The company set up its bomb disposal unit in concrete shelters in Vrijbos at Poelkapelle soon after the armistice.[24] The unit was on the Ypres–Kortemark railway line, adjacent to a British military camp and just south of the SDM munition destruction site.

On 24 April 1921, Belgian authorities and Pickett signed a contract to eliminate munitions of all calibres, their components and gas apparatus for use in trenches.[25] Article I of the contract required the Belgian state to furnish Pickett with at least 1000 tonnes of ammunition per month and a total of 15 000–16 000 tonnes in 10 months. The first 15 000 tonnes compensated Pickett for constructing a railway line into the compound where the munitions were stored. The firm was required to pay 13.5 francs per tonne (exclusive packing) for the remaining munitions (article III). The material which resulted from the dismantling and destruction process became the property of the company, but its shipment abroad was subject to export regulations and licensing in some instances (articles III and XIII). The contract provided for a permanent on-site representative of the Belgian Government, and CCR officials had access at all times. There was also an agreement which detailed safety precautions.

Article IX of the contract dealt extensively with the destruction of toxic shells. It focused on safety precautions related to ventilation, equipment and clothing and on emergency procedures and safety standards for dismantling munitions. The permitted methods of destruction were also enumerated: 'The liquid, corrosive and toxic compounds must be destroyed on-site, removed, transformed into harmless products, or disposed of in a borehole with a depth of 2.50 metres after they have been neutralized. The holes will be filled and closed by the Pickett company, at its expense, to the complete satisfaction of the Belgian authorities'.[26]

The manner in which Pickett proceeded is not entirely clear. It is claimed that even today nothing will grow in some parts of the former compound because toxic chemicals were disposed of by simply pouring them into the soil. If the Belgian Government's permanent representative did not act in complicity with the company to conceal what took place, there remain three possible explanations for the barren areas. First, something other than chemical agents may have caused the areas which lack vegetation. Second, if these areas are identical to the bore-holes, the chemicals which were placed in them may not have been adequately neutralized, or a mixture of the end products of decontamination may have been placed in each hole, resulting in a chemical reaction that poisoned the soil. Third, Pickett's standards for decontamination may have been lower prior to the intervention of Belgian authorities or when the first (known) decontamination activities were carried out under the 31 May 1920 contract.

[23] 'Letter to Lt.-Gen. Tollen, President of the CCR', London, 14 Sep. 1922, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French). The location is given as '22, Queen Anne's Gate, London SW'.

[24] The villages of Houthulst, Langemark–Poelkapelle and Westrozebeke border on each other just south of Houthulst Wood, which creates some confusion about the location of the installations. Although most official documents referred to Westrozebeke as the village where Pickett was located, presumably because of the proximity of Westrozebeke barracks, both the firm and the barracks were in Poelkapelle.

[25] 'Contrat entre l'Etat Belge et la firme 'Pickett' (F. N. Pickett et Fils à Wimereux, France)' [Contract between the state of Belgium and the firm Pickett (F. N. Pickett and Sons, Wimereux, France)] Brussels, 24 Apr. 1921, Dossier MDN, Cabinet, Commission Centrale de Récupération, Centre de Documentation Historique, Evere, (in French). Article XVII of the contract notes that it replaced an earlier 31 May 1920 contract.

[26] Quotes translated from French.

Article IX of that contract provides support for this supposition: 'The dismantling of gas shells will be done by following the methods approved by the President of the CCR to the letter'.

A 23 February 1922 letter from Lieutenant-General Tollen, President of the CCR, to the Minister of Defence[27] provides evidence that the installation initially processed green and yellow cross shells and that its work was satisfactory. However, a 15 September 1922 report stated that successful decontamination was achieved only by trial and error. The destruction processes for phosgene[28] and mustard gas each posed particular problems which led to delays, although in the end the decontamination was successful.[29] Blue cross shells appear to have posed significant problems during the start-up phase since, on 23 February 1922, Tollen asked to visit Pickett's special installation at Dannes, France, in order 'to avoid all miscalculations'.

The only surviving document which outlines Pickett's disposal methods in Poelkapelle is the report of a Belgian delegation. Based on the report, it appears that during the period of the May 1920 contract chemical compounds were burned in specially built furnaces rather than neutralized and then discharged into the soil. The report stated that although the processes for destroying different types of chemical warfare agents varied, the differences were relatively small, and an installation for the destruction of one gas could be used to destroy other gases as well. The installation in question was described as:[30]

essentially a furnace in refractory materials with a horizontal bottom, the furnace continued in: (1) a slightly inclined chimney consisting of a sandstone flue in which there is a continuous flow of water, (2) a horizontal chimney in refractory bricks with a length of 5 or 6 metres, (3) as a continuation of the first, a vertical chimney with a height of about 10 metres.

The flow of water circulating through the first enters the conduit through openings bored in the higher part and leaves it through an opening located at the lower end next to the point where the angled chimney and the horizontal chimney join.

The report also dealt with the methods of destruction for the main CW gases: chlorine, phosgene, yperite and the various contents of green cross shells. It noted that the processes in use were the correct ones and that the results were satisfactory. Although no ill effects were observed for the employees, the local

[27] 'Lettre du Lieutenant-Général Tollen, Président de la CCR au Ministre de la Défense Nationale' [Letter from Lt.-Gen. Tollen, President of the CCR to the Ministry of Defence], Brussels, 23 Feb. 1922, document no. 49386/A/2950, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

[28] The use of the terms 'phosgene' and 'green cross' in the documents is apparently based on the country of origin of the compound, not on chemical properties. For a discussion of the cross codes, see the subsection 'Colour coding using cross codes' in section II of chapter 6 in this volume.

[29] 'Lettre du Lieutenant-Général Tollen, Président de la CCR, au Ministre de la Défense Nationale' [Letter from Lt.-Gen. Tollen, President of the CCR, to the Ministry of Defence], Brussels, 15 Sep. 1922, document no. 52705/A/2950, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French), 3 pp. and annex.

[30] Institut d'Hygiène de Biologie et Chimie de l'Armée, 'Rapport par Paul Erculisse, Pharmacien de 1e Classe, Chef du Laboratoire de Chimie Toxicologique, Dr Sillevants, Médecin de Régiment, Chef du Laboratoire de Physiologie Toxicologique et le Capitaine-Commandant Vanden Berghe' [Report of Paul Erculisse, Pharmacist, Head of the Laboratory of Chemical Toxicology, Dr Sillevants, Regimental Physician, Head of the Laboratory of Physical Toxicology, and Captain-Commandant Vanden Berghe], document no. C/28, Brussels, 3 Mar. 1922, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

Table 15.1. Pickett et Fils production rates (explosive and chemical munitions)

	Deliveries to Pickett (tonnes)	Destroyed by Pickett (tonnes)	Percentage destroyed
First contract (31 May 1920–21 Apr. 1921)	10 200	1 800	*17.64*
Second contract (21 Apr. 1921–1 Sep. 1922)	22 230	26 130[a]	*117.54*
Total	**32 430**	**27 930**	***86.12*** [b]

[a] Included munitions not destroyed under the first contract.
[b] Percentage of destruction of total delivered.

Source: 'Lettre du Lieutenant-Général Tollen, Président de la CCR, au Ministre de la Défense Nationale' [Letter from Lt.-Gen. Tollen, President of the CCR, to the Ministry of Defence], Brussels, 15 Sep. 1922, document no. 52705/A/2950, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French), 3 pp. and annex.

population or vegetation, it was recommended that the furnace operators wear full protective clothing at all times. Depending on the tasks they were performing employees who did not work in the immediate vicinity of the furnace were to use gas masks or to have them ready to use (i.e., hanging from their necks). These precautions were deemed necessary since there was likely to be leaking from some of the 30–40 gas shell fillings which could be emptied at a single facility. It was feared that the accumulation of gas vapours during the lengthy destruction process could lead to serious chemical intoxication. The report noted that no chlorine or hydrochloric acid were present in the gas from the chimney and that there was therefore no danger to the area around the destruction facility.

In September 1922 Tollen wrote an extensive progress report on the work being carried out by Pickett.[31] It is the only known document which contains figures and charts (summarized in table 15.1). Tollen noted that Pickett had improved its destruction rates considerably from a monthly average of 189.5 tonnes, under the first contract, to 1686 tonnes, under the second contract. However, the monthly output varied considerably. During the start-up phase Pickett experienced serious difficulties, and seasonal and weather conditions also affected the destruction process.

Tonnage is not a reliable indicator of work volume. When work concentrated on munitions which required complex or multiple types of handling the output figures dropped significantly. Similarly, lower tonnage figures were reported when small munitions, such as grenades, were processed. By 1 September 1922 Pickett had received 7400 tonnes of gas shells from the Belgian authorities (22.82 per cent of the total of all munitions received) and had destroyed 510 tonnes of yellow cross shells, 4350 tonnes of blue cross shells and 2000 76-mm green cross shells. The report added that the SDM had 2300 tonnes of munitions in its stocks in addition to the munitions awaiting destruction at Pickett (approximately 2500 tonnes). Three-quarters of the total of approxi-

[31] 'Lettre du Lieutenant-Général Tollen, Président de la CCR, au Ministre de la Défense Nationale' (note 29).

mately 4800 tonnes of the munitions remaining were green cross shells, and one-quarter of the shells were yellow cross.

Tollen's report indicated that Pickett was constructing a second furnace, similar to the first, but even under optimal conditions the destruction of green cross shells would require another seven months (i.e., until March 1923). A 14 September 1922 letter from Pickett to Tollen hinted that the work might be completed sooner, after which Pickett wished to close the facility.[32]

Other private firms also destroyed munitions. There are no detailed records of these activities, and the name of only one firm, Emile Deckers of Schoten (near Antwerp), is known. It cannot be determined whether these firms worked independently or under government contract or if they treated toxic munitions. In addition, in 1918 the British military had set up a camp for the destruction of explosive and chemical munitions on the Ypres–Kortemark railway at Poelkapelle. Approximately 300 workers carried out destruction activities in two sheds, removing the toxic components from shells and then burning them. The camp closed in 1924.[33] Both Belgian and British troops also dumped large quantities of explosive and chemical munitions in the North Sea off the Belgian coast.

There is a gap in the history of Belgian munition disposal units until just before World War II. It is not known whether the units were disbanded or continued to exist under other names. Toxic munitions, however, continued to create problems for decades after the armistice, particularly for farmers and cattle breeders. An article in a veterinary journal described an incident in October 1935 in which a number of pigs were killed by phosphorus poisoning.[34] After months of investigation the cause of the poisoning was discovered when the owner of the pigs witnessed the spontaneous explosion of a phosphorus shell in a field where the pigs often grazed. In another incident a farmer obtained a large English shell which he requested a smith to convert to a roller. When holes were drilled in the shell to pass a shaft through it, the smith was nearly overcome by the mustard gas which was released.[35]

Toxic gases from unexploded World War I munitions were also discharged in Belgium in World War II during the May 1940 campaign. Cattle died when a bomb containing a mixture of phosgene and sulphur-containing phosphorus leaked, and investigations in August–December 1942 revealed that exploding shells had breached the soil in 1940 allowing toxic gases to contaminate the grass. Before World War II the area had been considered safe.[36]

32 'Lettre de Pickemetal au Lieutenant-Général Tollen, Président de la CCR' [Letter from Pickemetal to Lt.-Gen. Tollen, President of the CCR], Londres, 14 Sep. 1922, Dossier MDN, Cabinet, Commission Centrale de la Récupération, Centre de Documentation Historique, Evere (in French).

33 Craenen (note 13), p. 14.

34 Grains of solid phosphorus were found in the grass which the pigs ate. Before the cause was ascertained, there was speculation that someone had intentionally poisoned the animals. De Jonckheere, J., 'Vergiftiging van varkens door fosfor: Overdruk van het' [Poisoning of pigs by phosphorus], *Vlaamsch Diergeneeskundig Tijdschrift* [Flemish veterinary journal], vol. 6, no. 1 (Jan. 1937), pp. 8–11 (in Dutch).

35 'Een stikgasbom veroorzaakt bijna een erg ongeval' [A poison-gas bomb almost causes serious accident], *Het Ypersche*, 14 May 1938 (in Dutch).

36 Samyn, E. (Cdr.), 'Brief aan den Heer Caenepeel, Rijksveearts te Ieper, betreft "Verslag nopens schade aan hoornvee op het Zwaanhof te Boesinge", Commissariaat-Generaal voor's Lands Wederopbouw, Dienst voor Ruiming van Springstoffen' [Letter to Mr Caenepeel, State Veterinary in Ypres, concerning 'Report regarding damage to horned cattle of Zwaanhof [farm] at Boesinge', Commissioner-General for the Reconstruction of the Country, Service for the Removal of Explosives], Direktie. ref. S/3110, Westroozebeke, 7 Dec. 1942 (in Dutch).

III. Belgian chemical weapon production

Even less is known about the production of chemical warfare agents in Belgium in the 1930s than about Belgian use of chemical weapons. It is generally believed in political and military circles that Belgium never produced chemical munitions or prepared for offensive chemical warfare. However, a historical study of a fortress at Steendorp (a village near Temse, south-west of Antwerp) revealed that the Belgian military engaged not only in anti-CW research, but also that mustard gas and adamsite (DM) were produced just before World War II.[37] A letter by the commander of the SDM, Captain-Commander E. Samyn, refers to a contaminated area on the fortress's retaining walls, but no other documentary evidence of CW-related activities has survived or been publicly released.[38]

Experiences in World War I and debate after the war led Belgian authorities to consider chemical weapons as potentially decisive in a future war. Initially, the interest in these weapons may have been defensive, and international political developments may have influenced the decision to build up a small retaliatory capability—thereby concretizing Belgium's reservations of in-kind retaliation to the 1925 Geneva Protocol. Throughout the 1920s anti-gas personnel, sometimes conscripts with specialized degrees, were included in Belgian Army units. The Service de Protection contre les Gaz (SPG, service for protection against gases) was created in the mid-1920s and reported directly to the Minister of War. In addition to protection against CW, the SPG studied chemical warfare agents. Its headquarters were in Brussels. Laboratories were established at Vilvoorde, and a factory was eventually set up at Steendorp Fortress—the Ateliers d'essais et de contrôle du matériel anti-gaz (AMAG, workshop for the testing and control of anti-gas equipment). Steendorp Fortress was obsolete and had been declassified in 1924, after being partially destroyed in World War I. Nevertheless, the authorities denied a request by a civilian firm to build a factory within its perimeter because of the explosives and gas shells which were still present.

The construction of AMAG began in the latter part of 1928. Its main activities were the production and testing of anti-gas equipment, including gas masks, canisters and air filters for large areas. However, the manufacture of gas appears to have been one of the original purposes of the facility since the first buildings housed both a gas tank and a scrubber. In addition, there was a conduit made of varnished or glazed ceramic pipes, which was specially built to discharge liquid waste directly into the Scheldt River rather than into the existing sewerage system, and two large yellow-tiled concrete precipitation tanks for decantation—known locally as 'acid pits'. The facility system was not entirely ready until early 1934, and it can therefore be assumed that there was no significant production before that date. Part of the facility still exists.

[37] Colaes, R. and Gils, R., 'Fort Steendorp: een vestingbouwkundige, heemkundige en ecologische benadering' [Fortress Steendorp: an architectural, sociological and ecological approach], *Jaarboek 1991* (Gemeentemuseum: Temse, 1992), pp. 285–311 (in Dutch).

[38] Only three people, a workman, a maintenance worker and a person with general knowledge of the work, are known to be alive; they still keep the pledge of secrecy they were required to make. The authors collated the information on the basis of extensive interviews on a broad range of topics related to the history of the fortress. Gils, R. (Lt. Col., ret.), private communication with the author, 16 Apr. 1993. The following summary is done with his permission.

AMAG produced mustard gas and adamsite, and chloropicrin was produced once. Mustard gas was initially synthesized using ethene and sulphur dichloride. Production at AMAG was not continuous, usually consisting of one-week runs during which several 200-litre barrels were filled. These were either transported to Zwijndrecht Fortress (near Antwerp) for bulk storage or used for on-site filling of ammunition. Later, a German process was adopted which used thiodiglycol and hydrochloric acid. The thiodiglycol was purchased in France. Adamsite was synthesized on-site from diphenylamine and chlorarsine. Some open-air testing of adamsite shells was carried out at Steendorp Fortress. Red and white phosphorus were also manufactured and were tested at the Beverlo military camp. Production ceased in 1940.

When German forces invaded Belgium, AMAG stocks were transferred to the local tramway, which was built into the fortress, and then transported by train to a French gas facility in the Pyrenees. No other information is available about the operation.

IV. Sea dumping of old chemical munitions

Chemical munitions from World War I were dumped into the sea on three occasions: first, just after the war when Allied troops disposed of huge amounts of conventional and toxic ammunition off the Belgian coast near Zeebrugge; second, in 1954–72 when Belgium regularly dumped 'problem munitions' (i.e., those unable to be determined conventional munitions and therefore presumed to be CW) encased in concrete into the Gulf of Biscay; and third, in 1980 when there was a single, large dumping of problem munitions into the Gulf of Biscay.

As mentioned above, information about the disposal of ammunition between the two wars is sketchy as few, if any, records seem to have survived. This is particularly true of the dumping site near Zeebrugge. An official account of dumping there, prepared for a meeting of a technical group of the Oslo Commission, stated that in 1920 Belgian Armed Forces dumped an estimated 35 000 tonnes of munitions retrieved from the Flanders battlefields into the North Sea.[39] Shortly afterwards indications of the dump disappeared from sea charts. The dump was rediscovered in 1972 and is now marked on charts as the Paardenmarkt (horse market). Fishing and anchoring in the area have been banned. Measurements and surveys have been conducted to determine the size and potential risk of the dump.

The Paardenmarkt is located 1.5–3.5 km from the eastern wall of the external port of Zeebrugge and 1–2 km from the shoreline of Knokke, a major seaside resort. It covers 3.6 square km. At low tide, the seabed is approximately 4–5 metres deep. The munitions are known to be of German origin, and, based

[39] Ministère de la Santé Publique et de L'Environnement, Institut d'Hygiène et d'Epidémiologie, Unité de Gestion du Modèle Mathématique de la Mer du Nord et de l'Estuaire de l'Escaut, 'Munitions de gaz de guerre immergées au large de la côte belge' [Gas munitions from the war submerged along the Belgian coast], référence OSCOM 12/14/1, para 7.29, document présenté à la réunion du groupe technique 'SACSA' de la Commission d'Oslo [Document presented at the meeting of the SACSA technical group of the Oslo Commission], Copenhagen, 11–15 Mar. 1991, p. 1 (in French). The estimate was made based on the accounts of witnesses who stated that 300 tonnes were dumped daily in a 6-month period. Ministerie van Volksgezondheid en Leefmilieu, Instituut voor Hygiëne en Epidemiologie, Beheerseenheid Mathematisch Model Noordzee en Schelde-estuarium, 'Paardenmarkt: Interdepartementale evaluatievergadering, Verslag [The Paardenmarkt: an interdepartmental evaluation meeting, report], Brussels, 17 July 1990, p. 3 (in Dutch).

on German Army supply data, it is believed that chemical munitions (primarily 77-mm shells filled with mustard gas) comprise as much as one-third of the dump (11 600 tonnes). The shells, some of which remain in their original crates, are in good condition.[40] Most are now covered by at least one metre of silt, thus placing them in an anoxic environment and protecting them from the worst effects of erosion.

Salvaging companies, the Flemish section of Greenpeace and the municipal authorities of Knokke have lobbied to have the munitions removed. However, technical experts from various governmental departments concur that recovering the shells would pose a greater hazard to the marine environment and the coastal resorts than letting the munitions remain where they are. If the munitions were exposed to air, corrosion would occur, and an explosion during handling would endanger the lives of the salvagers. A report by a commission with representatives from the Defence, Public Works, and the Environment departments therefore concluded that the Paardenmarkt does not pose acute danger if anchoring and fishing prohibitions are respected and that the danger is less than in other areas, such as the Baltic Sea. Moreover, there have been no recorded accidents in the zone.[41] The commission recommended against recovery and suggested instead that the situation be monitored. Its conclusions were transmitted to the March 1991 meeting of the Standing Advisory Committee for Scientific Advices (SACSA) of the Oslo Commission, which adopted the recommendations in June 1991.[42]

Press reports in April 1989 of a survey of shipwrecks along the Belgian coast by the Ministry of Public Works caused political controversy over the Paardenmarkt. The Flemish daily *Het Volk* questioned official claims that the site posed no risk to Zeebrugge.[43] *Het Volk* claimed that the dump was a threat to tourists, and that this was compounded by the presence (and planned expansion) of a large liquid natural gas terminal at the end of the sea wall and the projected construction of a nearby underwater pipeline for Norwegian natural gas. Concern was also expressed about plans to build a marina next to the eastern mole. The spectre of a serious accident with a ship adrift—a scenario reminiscent of the capsizing of the British ferry *Herald of Free Enterprise* in March 1987 just outside Zeebrugge—was also raised. *Het Volk* accused the government of underestimating the potential danger in order to avoid a delay in the construction of three gas storage tanks. The Inspector General of the Ministry of Public Works and other officials claimed that the sea wall and liquid natural gas terminal had been built to resist both earthquake and explosion and that the risks were minimal.[44] (Zeebrugge is also a major NATO munition supply port.) Sus-

[40] Strubbe, J., 'Telefaxbericht ter attentie van de heer Oosthoek' [Telefax to the attention of Mr Oosthoek], Ministerie van Openbare Werken, Bestuur der Waterwegen, Brussels, 11 July 1989 (in Dutch), private archive; and Vraag no. 496 van de heer Loones van 8 december 1989, 'Noordzee–Gasberg–Onderzoeken–Opruiming' [North Sea–gas mountain–investigations–disposal], Belgische Kamer van Volksvertegenwoordigers, *Vragen en Antwoorden*, no. 97, Gewone Zitting 1991–1992 [Bulletin of written parliamentary questions], 13 Feb. 1990, pp. 7574–75 (in Dutch).

[41] Ministerie van Volksgezondheid en Leefmilieu (note 39), pp. 3–4.

[42] Vraag no. 163 van de heer Maertens d.d. 21 Jan. 1993, 'Gifgasmunitiestort "Paardenmarkt": Stand van zaken' [Poison gas munition dump 'Paardenmarkt': situation], Senaat, *Vragen en Antwoorden*, no. 51 (6 Apr. 1993), pp. 2413–14 (in Dutch).

[43] Vandenbussche, F., 'Bom onder Zeebrugge' [Bomb under Zeebrugge], *Het Volk*, 8 Apr. 1989, pp. 1, 2 (in Dutch).

[44] 'Tijdbom op de zeebodem' [Time bomb on the sea bottom], *Het Laatste Nieuws*, 10 Apr. 1989, p. 5; T. H., 'Openbare Werken onderzoekt munitiedepot in Noordzee' [Public works investigates munition

picion increased when a spokesman for the Distrigaz company, the owner of the terminal, declared that the dumped munitions had not been taken into account in risk analyses for the terminal because government officials had failed to inform the company about the dump.[45] The issue resurfaced in written parliamentary questions when the Minister of Public Works promised to conduct a thorough study. The study was apparently never completed, although the Ministry of Defence has conducted various other studies.

The only known Belgian policy on sea dumping dates from the period after World War II. No documents are known to exist about other sea-dumping operations between the wars, and there is little information about the handling of dangerous munitions in the years just after World War II. There are strong indications that between 1945 and the early 1950s toxic ammunition was disposed of along the Belgian coast.[46] After 1954 three navy frigates—the *Godetia*, the *Zinnia* and, in particular, the *Kamina*—carried out sea dumping, although Belgian authorities are reported to have initially chartered civilian vessels.[47] The dumping continued until 15 February 1972 when Belgium acceded to the 1972 Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (known as the Oslo Convention).[48]

During the 18 years between 1954 and 1972 Belgium dumped 810 tonnes of old dangerous munitions encased in concrete blocks into the Gulf of Biscay. The procedure was relatively straightforward. In Poelkapelle each munition was placed in a metal case; the cases were then grouped in concrete blocks. It is believed that the concrete casings were not strong or heavy and that munitions made up the larger part of the gross weight. The blocks were transferred by rail from Poelkapelle to Zeebrugge where they were loaded onto the frigates. Delays in Zeebrugge were usually minimal, and no special precautions were taken other than the standard safety procedures for any munition transport. As soon as they were loaded the ships departed for the Gulf of Biscay. Each shipment had a modest total weight.[49]

After signing the Oslo Convention Belgium immediately ceased its dumping operations and the munitions were stored outdoors in Poelkapelle. The stockpile

depot in the North Sea], *Gazet van Antwerpen*, 10 Apr. 1989, p. 9; and 'Rode bolletjes in kaart' [Red dots mapped], *Brugsch Handelsblad*, 14 Apr. 1989, pp. 1, 3 (all in Dutch). See also Strubbe (note 41).

45 Noterman, J., 'Knokke allait construire une marina sur un lit de bombes' [Knokke will construct a marina on a bed of bombs], *Le Soir Illustré*, 20 Apr. 1989, pp. 10–12 (in French).

46 Private communication, Apr. 1993. This deduction follows from the fact that before 1954 the Belgian Navy did not dump toxic munitions in the Gulf of Biscay and the Army did not stock or destroy them on land. It is apparently corroborated by a draft answer to a written parliamentary question, prepared by the General Staff of the Navy, stating that 'the positions of dumping zones of World War I munitions were well known'. The plural forms, used in both the French and Flemish draft, are significant. Letter from the Chief of Staff of the Navy to the Minister of Defence, reference ZS 404061, 16 May 1989 (in Dutch), private archive. The official reply made no mention of other dumping zones and stated that 'the position of sunken warships is well known'. Both documents state that there are no other 'similar' [to the one at Zeebrugge] dumping zones off the Belgian coast. Vraag no. 331 van de heer Van Dienderen van 28 Apr. 1989, 'Zeemacht: Berging van gevaarlijke tuigen voor de kust' [Navy: salvaging of dangerous contraptions off the coast], Belgische Kamer van Volksvertegenwoordigers, *Vragen en Antwoorden*, 1989 (in Dutch).

47 Ontmijningsdienst van de Landmacht, 'Bezoek Minister van Landsverdediging' [Bomb Disposal Service of the Army, Visit by the Minister of Defence], Poelkapelle, 15 May 1992, annex II-B, p. 1 (in Dutch).

48 Ratified on 8 Feb. 1978 and published in *Belgisch Staatsblad*, 4 May 1978. The Royal Decree of 7 Nov. 1983 implementing the ratification act was published in *Belgisch Staatsblad*, 25 Jan. 1984. The Oslo Convention is also discussed in chapter 18 in this volume.

49 Interview with Maj. De Vuyst, Commander of the Bomb Disposal Service, 6 Apr. 1993.

grew each year at an average of 20 tonnes. In the absence of other destruction procedures the Ministry of Defence reconsidered sea dumping. The government appointed an ad hoc technical committee composed of representatives of the ministries of Defence, Foreign Affairs and Transport, who recommended sea disposal. On 14 May 1980 the Minister for the Environment and Public Health invoked the 'emergency' provision of Article 9 of the Oslo Convention and issued a licence for dumping the accumulated stock of 225 tonnes of toxic munitions in the Gulf of Biscay. Strong international protests followed because the Belgian authorities informed the other contracting parties after the fact rather than consulting them prior to the decision as required by the Oslo Convention.[50] Finland, Ireland, the Netherlands, Norway and Sweden did not oppose the dumping operation as such but urged Belgian authorities to seek alternative methods of disposal. France made a reservation regarding the arsenic compounds, the proposed dumping site and the possible migration of the sunken munitions to the continental shelf. Only the Federal Republic of Germany formally opposed the entire operation.[51]

In contrast to the approach taken two decades earlier great attention was paid to environmental hazards, and the munitions were encased in 850–1250-kg reinforced concrete blocks which had been subjected to pressure tests. The munitions constituted 8.3 per cent of the gross weight of approximately 2700 tonnes. The Belgian authorities decided on a single operation, and a Danish ship was chartered because the frigates did not have adequate cargo capacity.[52] The dumping was carried out in November 1980. Since then the Army has stockpiled munitions under the open sky, more recently under roofing.

V. Description of the stock of old chemical munitions[53]

Each year the Bomb Disposal Service of the Army (Ontmijningsdienst van de Landmacht, ODLM) responds to 3000–3500 calls to remove old munitions and retrieves 200–250 tonnes of ammunition, the largest part in West Vlaanderen. Approximately 90 per cent of these old munitions can be positively identified as conventional munitions, and the ODLM regularly destroys them by underground explosion at their base in Poelkapelle. Large-calibre munitions, such as bombs from World War II, are detonated on the high sea with the assistance of the Navy in order to avoid structural damage to nearby private property from the resulting shock wave. The remaining munitions are considered 'problem munitions' since the exact nature of a particular artillery shell cannot be determined. Most are definitely toxic. Some are incendiary, smoke or tracer devices; some may be explosive but cannot be identified as such because of corrosion and decay.

[50] WM, 'Opruiming granaten Houthulst komt pas begin 1995 op gang' [Disposal of grenades at Houthulst will only start beginning 1995], *De Standaard*, 12 Jan. 1993, p. 8.

[51] Ontmijningsdienst van de Landmacht (note 47), annex II-B, p. 2.

[52] Interview with Maj. De Vuyst (note 49).

[53] This chapter is based on information and charts provided by the ODLM and interviews with Maj. De Vuyst (note 49) and Cdr. Alfons Vander Mast (14 Apr. 1993) of the ODLM, unless otherwise noted.

Table 15.2. The evolution of the stocks of toxic munitions, 1980–96

Year	Annual tonnage	Cumulative tonnage
1980	2	2
1981	18	20
1982	16	36
1983	18	54
1984	20	74
1985	19	93
1986	20	113
1987	16	129
1988	26	155
1989	15	170
1990	18	188
1991	9	197
1992	13	210
1993	18	228
1994	16	244
1995	17	261
1996	28	289

Source: Bomb Disposal Service, 1993; and private communication with Cdr. Alfons Vander Mast of the Bomb Disposal Service of the Army (ODLM), 30 Jan. 1997.

Table 15.2 shows that an annual average of slightly more than 17 tonnes of such munitions was retrieved in 1981–96.[54] The ODLM believes that the annual figures may begin to drop, although such a trend could also be the result of the introduction of automatic cleaning equipment that enabled better identification of individual munitions.

Official statements quote an average annual figure of 20 tonnes of munitions to account for unexpected large finds, but the discovery of a single dump could upset the statistical prognosis. In November 1988 a large German munition dump was unearthed, consisting of 165 mustard gas shells from the Battle of Berlare on the Schelde River. This single discovery accounts for the peak value that year. More recently, on 25–26 July 1993 heavy rains uncovered 28, 77-mm German chemical shells, each weighing approximately 7 kg, near the Flemish town of Ninove.[55] In August 1993 concern was expressed that roadwork in Monceau-sur-Sambre (just outside Charleroi in the Walloons) would disturb a site where the British are believed to have buried approximately 40 tonnes of German shells, presumably filled with mustard gas, in a seven-metre deep ditch which they subsequently covered with slate.[56] Confirmation of the dump's exis-

[54] The figure for 1980 is low because all recovered munitions for the period which presented a problem were dumped in the Gulf of Biscay.

[55] DSG, '28 gasbommen opgegraven' [28 gas bombs unearthed], *Het Laatste Nieuws*, 26 July 1993. The article suggests that the German shells are from a World War II munition dump. According to Cdr. Alfons Vander Mast (Private communication, 5 Aug. 1993) the shells are similar to those from World War I which are stored at Poelkapelle. The shells were discovered on a hill that dominates the region, and which was used by German forces as a gun emplacement in World War II. The shells are corroded and decayed, and it is no longer possible to determine whether they were fired. However, the quantity which remains strongly suggests that they were not fired. Ninove was still several km behind the German front line at the time of the armistice.

[56] BW, 'Mosterdgas houdt Monceau-sur-Sambre in de ban' [Mustard gas keeps Monceau-sur-Sambre in spell], *De Morgen*, 18 Aug. 1993, p. 4. (in Dutch).

tence and its subsequent removal to Poelkapelle would alter the statistical prognosis. When work on the Ypres–Veurne motorway resumes, it can be expected that large quantities of World War I munitions will be unearthed since the proposed route will essentially follow the former front line. Some major finds of dumps with toxic munitions were made in 1995 and 1996.

Storage methods for old munitions have evolved considerably since World War II. Initially, munitions were piled in long rows of shells placed on top of each other in open wooded areas. In the early 1980s, when long-term storage of toxic munitions became necessary, eight concrete platforms were constructed—each with a surface greater than 90 square metres and separated by earthen blast walls—to limit damage in the event of accidental detonation. Smaller 'pyramids' of a maximum of 25–50 shells (depending on calibre) were stored in U-shaped metal frames. This enhanced security, but a review of storage procedures and methods was necessitated by an accident on 7 May 1986 in which eight gas shells exploded killing four persons.[57] This led to the introduction of box pallets in December 1988 (a storage method similar to that used for wine bottles). Wooden partitions prevent physical contact between the shells, thus sharply reducing the risk of 'sympathetic explosion'. The shells are placed so that the detonators do not face each other. Box pallets also reduce handling. If a box pallet is placed on the back of a lorry, personnel can place retrieved shells in it. Once back at the military base a fork-lift truck can unload the box pallet and its contents. This method facilitates the relocation of munitions and their eventual transfer to a dismantling facility. Currently, the pyramidal storage method is in use on only one platform. Shells are also placed under moveable roofs to reduce the effects of sun and rain.

Leaking munitions, especially those filled with persistent mustard gas, pose a particular hazard. Shells which can be identified and easily retrieved are placed in airtight containers filled with active carbon or are encased in plaster. Such shells represent fewer than 0.34 per cent of the gross weight of stored munitions. In most cases a faint odour reveals the presence of a leaking shell. Reports are prepared about such observations, but no further action is taken. Searching for the leaking shells would expose personnel to unnecessary risk since the three storage methods—dumps, pyramids and box pallets—would make it necessary for potentially unstable munitions to be handled.

All casualties since World War II have been caused by explosions, not gas. An explosive ordnance disposal (EOD) robot, was acquired in April 1991 but is not often used. It can be employed to place munitions in box pallets and for other handling during dismantling. In rare cases a shell may detonate or release its contents spontaneously as a result of decay—when a seeping chemical starts a reaction—or because of the action of temperature and humidity. Such an incident took place on 21 May 1992, when a 150-mm shell ruptured, releasing a white cloud. There were some personnel in the vicinity, but there were no casualties. Immediate investigation of the area by a person wearing nuclear, biological and chemical (NBC) protective clothing revealed no traces of a CW agent,

[57] The subsequent investigation found that the 4 soldiers died from the explosion and had not been affected by the gas.

Table 15.3. Summary of munitions at Poelkapelle

Munition type and calibre	Nationality	Number stocked
Grenades	Various	143
Cylinders	German	12
77-mm shells[a]	German	15 493
105-mm shells	German	3 973
150-mm shells	German	875
170-mm shells	German	76
210-mm shells	German	61
60-pounder shells	British	739
4-inch Stokes mortars	British	33
Livens mortars	British	136
4.5-inch shells	British	2 296
6-inch shells	British	113
Total		**23 950**

[a] This category also includes 75-mm and 76-mm shells. According to detailed statistics based on 1991 data prepared for the consulting agency Coppée–Courtois, there were only 200, 75-mm and 76-mm shells and mines compared with 10 508, 77-mm shells. Less than 5% of the ammunition in this class is of French origin. British shells amount to only a handful. Vander Mast, A. (Cdr.), private communication, 5 Aug. 1993.

Source: Bomb Disposal Service, 1 Apr. 1993; and private communication with Cdr. Alfons Vander Mast of the Bomb Disposal Service of the Army (ODLM), 30 Jan. 1997.

nor did a more thorough technical investigation some hours later by a member of the Technical Service of the Army (based in Vilvoorde, outside Brussels).[58]

There are also toxic munitions in two additional dumps and on five of the eight platforms. The munitions are distributed on the platforms by calibre and sometimes by country of origin, and several platforms will gradually reach full storage capacity simultaneously. At the end of 1994 a sixth platform was filled, leaving only two platforms for temporary stockpiling of explosive munitions. The depot at Poelkapelle is rapidly reaching its maximum storage capacity, and the government has therefore been forced to act to open the dismantling facility as soon as possible. It would be unsafe to construct additional platforms since there must be adequate distance between the platforms and between the platforms and the perimeter road, the administrative buildings and the nearby Army munition depot. Each platform has a storage limit in terms of net explosive weight. In the case of toxic shells, however, the net weight of the burster charge is much lower than that of explosive munitions. Only 10 per cent of the permitted net explosive weight per platform is attained with the current storage method, and storage capacity is limited instead by volume.

In January 1997 the two dumps and five platforms held a total of 23 950 shells, grenades and other devices that were either filled with toxic substances or which could not be positively identified as explosive munitions (see

[58] 'Duitse gifbom ontploft' [German poison bomb explodes], *Het Laatste Nieuws*, 23 May 1992, p. 1; and NT, 'Gasbom barst open op DOVO-domein' [Gas bomb bursts open at DOVO site], *De Standaard*, 23 May 1992, p. 13 (in Dutch). A local action group claimed that several of the military personnel had to be treated in hospital for the effects of mustard gas and that the remainder of the liquid was hosed away, contaminating a nearby small river. The Ministry of Defence and an ODLM spokesperson denied the charges. For a review of these claims, see Driesmans, R., 'Bomincident: "sneller ontmantelen"' [Bomb incident: 'accelerate dismantling'], *Het Laatste Nieuws*, 25 May 1992 (in Dutch).

table 15.3). The vast majority (85.5 per cent) are of German origin, and 77-mm artillery shells alone make up more than 65 per cent of the total. The detonators in these shells used the state-of-the-art technology of that time. However, World War I did not allow sufficient time for thorough field testing, and an estimated 30 per cent of the shells are 'duds'. The Allied economic embargo forced Germany to use inferior materials and further reduced the reliability of the detonators. The detonators of these old German shells often rot and fall off, but part of the fuse may remain inside a shell and can cause it to explode.

The ODLM estimates the minimum net volume of toxic compounds at 5000 litres and the maximum at 25 000 litres. The divergence can be attributed to allowing for variations in the amount of CW agents in the shells, losses due to leaking munitions and a margin for explosive munitions which currently cannot be identified as such. The cumulative net weight of CW agents is believed not to exceed 10 tonnes.[59] The consultancy company Coppée-Courtoy identified 48 different product combinations which may be present in the munitions on the basis of an analysis of the relevant literature; they include: CW agents in the narrow sense as well as irritants and harassing agents, smoke devices and incendiaries. These compounds constitute a subset of all agents or combinations used in World War I. Documented use on the Belgian sector of the front appears to have been a major determinant in narrowing down the list of possible toxic compounds.

VI. The dismantling facility: a brief overview of the policy-making process

After the final dumping operation in November 1980, the Ministry of Defence began looking into alternative ways to dispose of dangerous munitions. In 1984 experts visited chemical demilitarization facilities in the Federal Republic of Germany, France and the United States. The visit to Kampfmittelbeseitigungsanlage der Bundeswehr (chemical munition disposal facility of the German Armed Forces) in Munster led to further negotiations with the West German Ministry of Defence which resulted in a draft agreement on ad hoc technical assistance in 1987.[60]

Initially, technological obstacles and lack of experience with CW destruction precluded a rapid solution to the problem. The political decision-making process and debate about departmental responsibilities further postponed its resolution. In the latter half of the 1980s, the proposed solutions ranged from returning the shells to the countries of origin to having them destroyed at the Munster facility. The former proposal was impractical because in many cases it was impossible to identify the individual munitions and because it would have led to diplomatic difficulties. The latter idea was abandoned because transport across Belgium and part of Germany was considered too hazardous. The elimination

[59] Ontmijningsdienst van de Landmacht (note 47), annex III-D, p. 1.

[60] The document was apparently never formally signed. Ontmijningsdienst van de Landmacht (note 47), annex II-B, p. 2. The same wording was used in the brochure issued for the ceremony to mark the beginning of construction of the dismantling facility. Ontmijningsdienst van de Landmacht, 'Ontmantelingsinstallatie voor de Toxische Chemische Munitie' [Dismantling facility for toxic chemical munitions], Poelkapelle, 21 June 1993, p. 3 (in Dutch).

of these alternatives led the government in January 1989 to its only possible option—construction of a dismantling installation at Poelkapelle.[61]

A complex set of factors affected the decision-making process. At the end of the 1980s the unstoppable growth of Belgium's public debt caused political concern and forced ministers to cut spending in their departments. After the demise of the Warsaw Pact there were many demands on the Ministry of Defence as various quarters tried to collect the so-called peace dividend. Meanwhile the estimated cost of the destruction facility rose from an estimated 150 million Belgian francs in 1989[62] to 500 million francs three years later. Operational costs, including personnel costs, were estimated at 65 million francs for the first year and at 55 million francs per year thereafter.[63] The Ministry of Defence declared that it was unable to shoulder the burden of investment alone and sought to share the cost with other ministries. A proposal to seek European Community (EC) funds on grounds that the problem arose from a European war involving several current major EC members failed to materialize.

A second important factor was the federalization process in which specific executive powers were transferred from the federal government to the regions and linguistic communities. As a consequence, it was unclear for some time whether a federal or a regional ministry would have to share the financial burden. The old chemical munitions at Houthulst and in the North Sea are located on Flemish territory. Technically, the question of the *Paardenmarkt* was resolved by acceptance of the recommendation that it was safest to let the old munitions remain in the sea sediment. Politically, it was settled by the position taken by the Council of State on a bill to prohibit storage of chemical weapons on Belgian territory.[64] The Council of State asserted that the region's competence regarding public works was limited to those areas necessary for the execution of responsibilities under the constitution transferred to the regions; thus the problem of old toxic munitions had to be resolved at the federal level. Presumably, the federal government shared the opinion of the Council of State, and the Ministry of Defence conducted further negotiations with the federal Ministry of the Environment rather than with the regional Flemish departments of the environment or public works.

[61] Reply by Defence Minister Guy Coëme to questions in the Senate, reported in 'Overheid bouwt installatie voor ontmanteling gasbommen' [Authority builds installation for dismantling gas bombs], *Financieel Economische Tijd*, 17 Jan. 1989, p. 24; ESN and MDW, 'Plannen ontmantelingsinstallatie oude munitie over half jaar klaar' [Plans for dismantling facility for old munitions ready in half a year], *De Standaard*, 17 Jan. 1989; ESN, MDW and VKV, 'Gasbommen worden ontmanteld' [Gas bombs to be dismantled], *Het Nieuwsblad*, 17 Jan. 1989; and EW, 'Coëme belooft gifgasbommen te ontmantelen' [Coëme promises to dismantle gas bombs], *De Morgen*, 17 Jan. 1989, p. 6.

[62] Vraag no. 361 van de heer Van Dienderen van 9 juni 1989, 'Houthulst, Uitschakeling gasbommen' [Houthulst: elimination of gas bombs], Kamer, *Vragen en Antwoorden*, no. 69, 18 July 1989, p. 5577 (in Dutch).

[63] Vraag no. 34 van de heer Van Hooland van 3 juni 1992, 'Vernietiging van mosterdgas in Houthulst' [Destruction of mustard gas in Houthulst], Senaat, *Vragen en Antwoorden*, no. 15, 21 July 1992, p. 631 (in Dutch).

[64] Eerdekens, C., Collart, J. and Onkelinx, L., 'Proposition de Loi relative à l'interdiction de la fabrication, du dépôt et de l'utilisation, par la Belgique, d'armes chimiques, Avis du Conseil d'Etat' [Bill pertaining to the prohibition of the production, storage and use of chemical arms by Belgium, comment by the State Council], Chambre des Représentants de Belgique, Session ordinaire 1988–89, no. 739/3, 8 Jan. 1990, p. 6 (in French).

The political debate accelerated after the January 1989 Paris Conference on the Prohibition of Chemical Weapons.[65] At the conference a Belgian military expert expressed concern about the danger the CW stocks posed to people and the environment.[66] Subsequent press reports and television pictures of decaying shells at Poelkapelle led to the creation of a local action group that began lobbying efforts with local, provincial and national politicians. Their campaign resulted in the establishment of emergency plans for use in the event of an accident and extension of the existing air exclusion zone over the storage site. Perhaps more importantly, the group managed to place the issue high on the national political agenda and local MPs began questioning the Minister of Defence at regular intervals. The ODLM and the action group, supported by the peace movement and local politicians, became allies in a common cause to lobby the government from both within and outside the establishment.[67]

On 2 June 1989 the government took the decision to build a dismantling facility at Poelkapelle, and the Ministry of Defence budgeted an additional 150 million francs for 1989–92 to cover the cost, one-tenth of which was earmarked for a technical study.[68] A protocol was subsequently signed with the Department of the Environment to determine the respective responsibilities for the dismantling and destruction of the munitions and the budgetary implications.[69] Soon afterwards replies to written parliamentary questions indicated that both ministries had launched preparatory scientific and technical programmes in their respective areas in anticipation of construction of the dismantling facility. The protocol also outlined basic responsibilities: the Ministry of Defence was to take care of the dismantling of shells, and the Ministry of the Environment was to actually destroy the toxic compounds. The Minister of Defence declined to respond to questions about the destruction process.[70]

Following various preliminary studies by consulting firms, the Brussels-based firm Coppée-Courtoy was awarded a contract on 4 November 1991 to prepare a detailed report.[71] Burning the CW agents was the preferred option,

[65] For a discussion of the conference, see Lundin, S. J., 'Chemical and biological warfare: developments in 1988', *SIPRI Yearbook 1989: World Armaments and Disarmament* (Oxford University Press: Oxford, 1989), chapter 4, pp. 116, 129–30; and Lundin, S. J., 'Multilateral and bilateral talks on chemical and biological weapons', *SIPRI Yearbook 1990: World Armaments and Disarmament* (Oxford University Press: Oxford, 1990), chapter 14, pp. 534–35.

[66] Doornaert, M., 'België betaalt hoge prijs voor afbraak chemische wapens' [Belgium pays a high price for demolition of old chemical weapons], *De Standaard*, 11 Jan. 1989, p. 1 (in Dutch). The article misquoted the expert, reporting that the stockpile was 160 000 tonnes instead of 160 000 kg.

[67] The action group did not respond to a request for an interview or provide written information. It is not known if the group still exists or what it now has as its agenda.

[68] 'Ontmantelingsinstallatie gasgranaten in Poelkapelle' [Dismantling facility for gas shells in Poelkapelle], *Het Nieuwsblad*, 3 June 1989, p. 10 (in Dutch); and '"Feu vert" à un centre de destruction des armes chimiques près d'Ypres' [Green light for a centre for the destruction of chemical arms at Ypres], *La Meuse*, 8 June 1989, p. 10 (in French).

[69] Vraag no. 361 (note 62).

[70] Vraag no. 553 van de heer Van Steenkiste van 6 februari 1990, 'Houthulst–Chemische munitie–Eindrapport' [Houthulst–chemical munitions–final report], Kamer, *Vragen en Antwoorden*, no. 104, 3 Apr. 1990, p. 8284; Vraag no. 164 van de heer Ghesqière van 28 september 1990, 'Chemische wapens-Ontmantelngsinstallatie te Houthulst' [Chemical weapons-dismantling facility at Houthulst], Senaat, *Vragen en Antwoorden*, no. 9, 4 Dec. 1990, p. 363; Vraag no. 36 van de heer Kuijpers van 12 december 1990, 'Verbrandingsinstallatie voor gifgassen te Houthulst-Mosterdgas' [Incineration facility for poisonous gases at Houthulst: mustard gas], *Bulletin van Vragen en Antwoorden-Senaat*, no. 14, 15 Jan. 1991, p. 578; and Vraag no. 37 van de heer Kuijpers van 12 december 1990, 'Ontmanteling van chemische wapens' [Dismantling of chemical weapons], Senaat, *Vragen en Antwoorden*, no. 17, 5 Feb. 1991, pp. 727–28 (in Dutch).

[71] Ministerie van Volksgezondheid en Leefmilieu, Dienst Sanitaire Bouwkunde, 'Studieovereenkomst inzake de vernietiging van toxische chemische afval opgesteld in de installaties van de Ontmijningsdienst

and the Ministry of the Environment requested that Coppée-Courtoy propose the best incineration methods for various compounds and contaminated equipment as well as methods for disposing of chemicals which could not be burned. Special consideration had to be given to the effect on the environment of the alternative methods, and Coppée-Courtoy was asked to design containers for CW agents which could be burned without endangering the environment and which were inexpensive. The study also addressed transport and general costs, and Coppée-Courtoy was required to submit specifications and other information to the Ministry of Defence about the construction and operation of the dismantling facility.

The contract was an important policy-making document for two reasons. First, the Ministry of the Environment defined its options clearly. Second, progress by the Ministry of Defence on its construction project depended on the recommendations of the feasibility study. Its conclusions also determined the final apportionment of costs between the two departments. The comprehensiveness of the contract masked the disagreement between the two ministries. It can also be assumed that the linguistic factor played a role,[72] since the departments had been headed by ministers from different linguistic groups in the past two governmental coalitions.[73] The contract did contain passages—on impending debates on cost-sharing and the dependence of the Ministry of Defence on the results of the feasibility study—that appeared likely to rekindle debate. The Ministry of Defence denied its responsibility for missed deadlines by referring to its dependence on the Coppée-Courtoy study. In a reply to a written parliamentary question, the Minister of Defence declared: 'It is regrettable that the instruction to realize the study of the Environment's tasks, the conclusions of which are necessary for the start of the realization of the work of the Ministry of Defence, was only given by that department early in November 1991. The study's results are expected in August 1992'.[74]

Other elements apparently also played a role. Coppée-Courtoy reportedly delayed signing the contract for almost 10 months,[75] and the study revealed several technical problems related to the proposed destruction process that had to

van de Landmacht te Poelkapelle' [Study contract pertaining to the destruction of toxic chemical waste stored at the facility of the Bomb Disposal Service of the Army at Poelkapelle], Onderhandse Overeenkomst, GSB/ENV/5109. Brussels, 4 Nov. 1991, 8 pp. and annexe.

[72] Neervoort, F., 'Als de wereld van zijn gifgas af wil, wil België het wel voor iedereen opslaan' [If the world wants to get rid of its poison gas, Belgium is willing to store it for everybody], *Vrij Nederland, vol.* 50 (14 Jan. 1989) (in Dutch). This Dutch journalist linked the debate on cost to the appropriation of 40 billion Belgian francs for the purchase of several weapon systems, contracts which would benefit the ailing Walloon defence industry.

[73] Until early 1992 the Defence Minister was Guy Coëme (francophone Socialist), and the Secretary of State of the Environment attached to the Prime Minister was Miet Smet (Flemish Christian Democrat). Leo Delcroix (Flemish Christian Democrat) was Defence Minister. Laurette Onkelinx (francophone Socialist) was Minister of the Environment and replaced in 1993 by fellow party member Magda De Galan.

[74] Vraag no. 1 van de heer Loones van 17 maart 1992, 'Chemische munitie: Ontmantelingsinstallatie' [Chemical munitions: dismantling facility], Senaat, *Vragen en Antwoorden*, no. 5, 12 May 1992, pp. 222–23 (in Dutch).

[75] Driesmans, R., 'Ontmanteling gasbommen kost 200 miljoen fr. duurder dan voorzien was' [Dismantling gas bombs costs 200 million francs more than anticipated], *Het Laatste Nieuws*, 27 Feb. 1992, p. 33 (in Dutch). This accusation was made by Senator Maria Tyberghien-Vandenbussche (Flemish Christian Democrat) defending the record of her fellow party member, the Secretary of State of the Environment. See also 'Senator Maria Vandenbussche zet haar kruistocht tegen toxische oorlogsbommen verder' [Senator Maria Vandenbussche continues her crusade against toxic war bombs], *Het Wekelijks Nieuws*, 1 May 1992 (in Dutch).

be addressed before further progress could be made. In November 1992 the ministries of defence and the environment, headed by new ministers, signed a second protocol, replacing the first, which detailed their responsibilities regarding preparations and execution of the dismantling and destruction processes and their respective budgetary commitments for the construction and operation of the dismantling facility. On 27 November 1992 the Ministerial Council approved the awarding of the building contract to the Roegiers-Soberi company. In early May 1993 Parliament approved supplementary budgetary allocations for both ministries: 240 million francs for the Ministry of the Environment and 264 million francs for the Ministry of Defence. Construction of the facility was completed by the end of 1994.[76]

VII. The dismantling facility: a brief overview of planned procedures[77]

In 1989 Flemish public television broadcast pictures of the storage site at Poelkapelle. Memories of World War I gas casualties and pictures of the chemical warfare victims of the 1980–88 Iraq–Iran War may have contributed to the demand by those living near the facility for the immediate and safe destruction of the old chemical munitions stored there.

On 21 June 1993 the ministers of Defence and the Environment laid the first stone of the dismantling installation. The complex has three major components: the identification, the dismantling and the decontamination buildings. The facility has been designed to provide maximum security for the personnel handling the toxic munitions, the workers in an adjacent facility and the people living in the surrounding villages.

The purpose of the identification building (figure 15.1) is to determine the nature of the munitions. After initial cleansing, a munition is placed on a conveyor belt by a 'loader', who describes its external characteristics to an operator in the control room via an intercom. The rest of the process is highly automated. The shell is automatically weighed and transported to a corundum blaster for cleansing and then automatically transported to the radioscopy chamber for inspection of its interior. The use of X-rays allows for unambiguous identification of the munition and choosing of the most appropriate dismantling method. The shell is then marked with symbols for this information and placed on a pallet for interim storage. The data which has been gained, including the X-rays, is stored on an optical disc, which accompanies the munition during its dismantling.

The second phase, dismantling, is the most complex (figure 15.2). Here, too, most operations are automated. The procedure to be used is chosen based on whether the toxic compound is liquid or solid. A munition with liquid contents

[76] Wetsontwerp houdende aanpassing van de algemene uitgavenbegroting van het begrotingsjaar 1992-secties ministerie van Volksgezondheid en Leefmilieu en ministerie van Landsverdediging [Bill pertaining to correction of the overall expenditure budget for the budgetary year 1992: sections Ministry of Public Health and the Environment and Ministry of Defence], Kamer van Volksvertegenwoordigers van België, 48e Zittingsperiode-1992–93 GZ-Handelingen-PLEN, 5 May 1993, pp. 224–26.

[77] This section is based on information and charts provided by the ODLM and interviews with Maj. De Vuyst (6 Apr. 1993) and Cdr. Alfons Vander Mast (14 Apr. 1993) of the ODLM, unless otherwise noted.

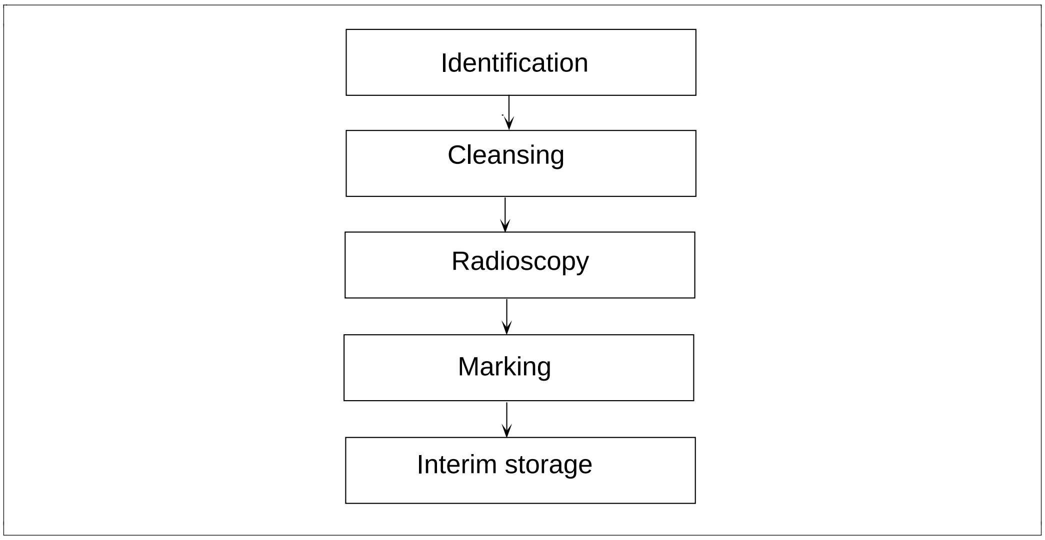

Figure 15.1. Procedures in the identification building

is placed on the conveyor belt by a loader wearing full protective clothing, under the guidance of an operator in the control room. The shell is secured and placed under a gas-tight bell, and a hole is made in it by an automatic drill. A sample of the contents is analysed in the laboratory to determine the exact composition of the toxic agent. Based on this analysis the contents are pumped to the appropriate container using the pressure–underpressure principle. Phosgene is the only CW agent which can be completely neutralized in the dismantling facility. Its high toxicity makes it dangerous in a confined space, and it must be processed by a phosgene scrubber. The shell casing is subsequently rinsed and chemically decontaminated. It is then placed on a pallet with other explosive ammunition to await destruction.

Shells with solid contents are placed in a milling cutter by a loader wearing full protective clothing. The X-ray film on the optical disc helps the technicians determine the exact point which separates the detonator and explosive part of the shell from the rest of the munition. After milling, the detonator is automatically removed for decontamination and is later destroyed together with other explosive ammunition. The remaining part of the shell is handled manually in order to separate the toxic components from any remaining explosive substances. The components are then packed and stored in special containers pending removal or destruction.

Treatment of liquid and solid agents takes place in separate sections of the dismantling facility, and both operations can proceed simultaneously. Shells with both liquid and solid contents are processed using a combination of the above procedures, which is determined by analysis of the munitions.

The third major component of the complex is the decontamination building (figure 15.3). Personnel pass through it when entering and leaving the dismantling building. When entering, they undress completely and put on underclothing and full protective clothing with an autonomous breathing apparatus. They are then driven to the dismantling building.

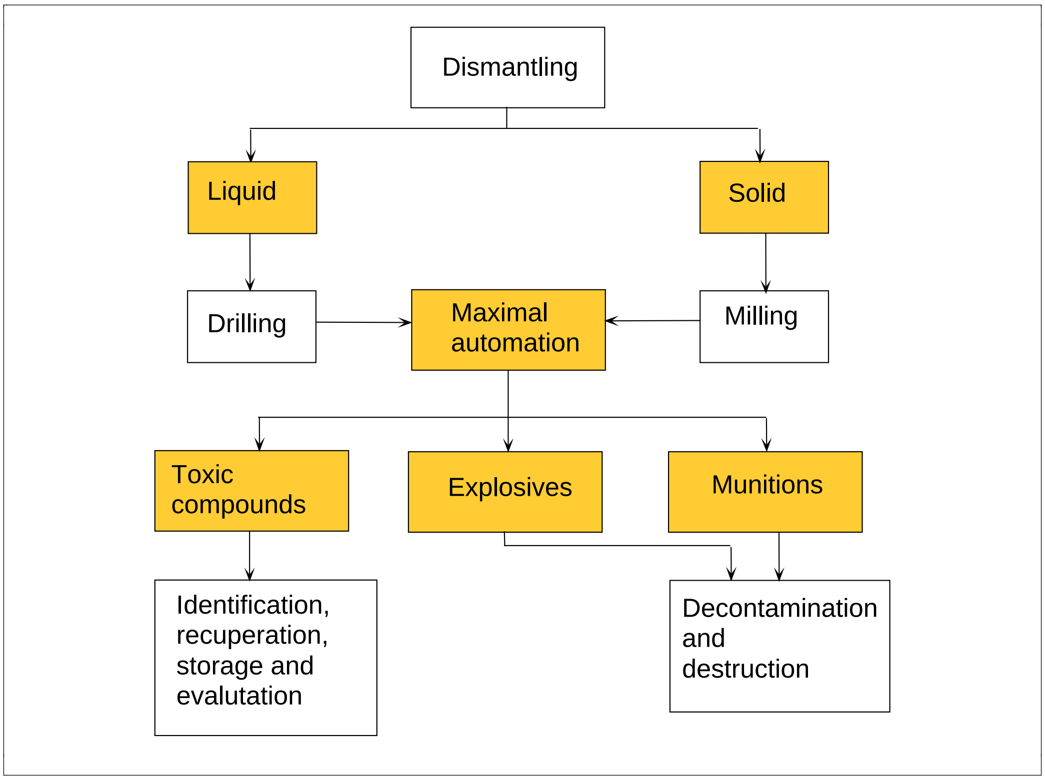

Figure 15.2. Procedures in the dismantling building

At the end of the workday, the personnel are again driven to the decontamination area. They enter immediately and undress completely, following a procedure to avoid contaminating the inside of their protective suits. The clothing is then transferred to a separate room to be decontaminated and cleansed after which it remains in a drying chamber for 24 hours. It is checked, tested, repaired (if necessary) and then stored in the stockroom. The breathing apparatus is also decontaminated and the underclothing washed. The personnel first walk through a 'rinsing' area and then proceed into a shower, where they wash thoroughly. They proceed to the dressing room where their collect their personal belongings and then leave the building through an airlock.

When it is working at full capacity the dismantling facility can process 8–10 shells per workday and approximately 2000 munitions annually. In 1993 it was estimated that the then existing stock of approximately 18 000 munitions could be disposed of in less than 9 years. (Coppée-Courtoy had calculated that 7.5 years would be needed.) Some of the munitions are of the explosive type, and these will not need to be dismantled. They can be destroyed at Poelkapelle. More chemical shells will be found, and if they continue to be located at the current rate, it will take approximately 15 years to dismantle all of them.

Interim storage of the CW agents and toxic waste is ultimately the responsibility of the Ministry of Defence. Under its research contract with the Ministry of the Environment,[78] Coppée-Courtoy was required to propose a design for a

[78] The Ministry of the Environment did not respond to a request for an interview. The information summarized here is compiled from unclassified charts and working documents provided by the Ministry of Defence and the ODLM and from comments and explanations given in interviews. This section of the

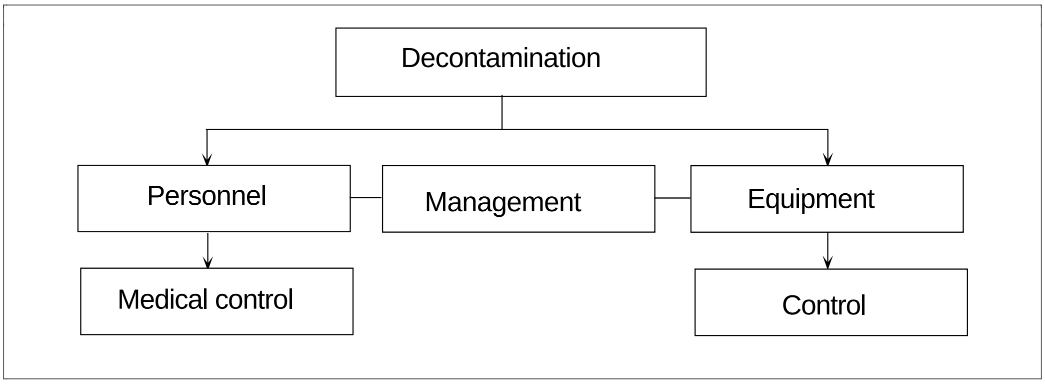

Figure 15.3. Procedures in the decontamination building

storage container that can resist the corrosive effects of CW agents and be ecologically destroyed together with its contents. A 20-litre polyvinyl chloride flask may meet these requirements. The contents of one shell would be emptied into each such flask in order to avoid unexpected chemical reactions that could be caused by mixing two different agents or agents tainted by chemical reactions within a munition. Exceptions could be made if chemical analysis proved that the contents of two shells had exactly the same composition. The storage problem is further complicated by the diversity of dangerous chemical substances, which can be irritating and toxic and also simultaneously explosive or flammable. Moreover, some materials such as solvents are toxic, although they may have been used for other purposes. Unexpected chemical compounds may be present as a consequence of reactions with shell casings or because a CW agent has seeped into the burster charge. It may be possible to dispose of such munitions by a controlled explosion, but it is not clear if this would have other unwanted effects, such as the release of noxious fumes.

The actual destruction process will be carried out by the Antwerp-based Indaver company, the only company in Belgium able to process the kind of toxic waste that results from dismantling chemical munitions. Indaver will not accept some compounds for processing, and these substances would be hazardous to store or transport. The compounds in question are highly flammable white phosphorus and combinations of white phosphorus with celluloid, molasses, carbon disulphide and carbon disulphide and tar oil. The only alternative is to destroy them by explosion at Poelkapelle, but this generates toxic fumes in the form of phosphorus pentoxide (P_2O_5) and phosphoric acid (H_3PO_4).

The various steps of the burning process can only be determined after the composition of the CW agents has been determined in the dismantling unit. Some serious problems were identified and the Minister of the Environment commissioned at least two universities to conduct supplementary research, some of it confidential. In late summer 1993 the Minister of the Environment ordered a study on the lethality of World War I CW agents.

chapter is added to indicate the problems involved and cannot be considered as complete or as the policy of the Ministry of the Environment.

Appendix 15A. Chemical attacks on the Belgian front, 1915–18

Date	Location	Type of attack	Comments
1915			
14 Feb.	Belgian sector, north of Ypres salient	Tear-gas (T) shells	2 Belgian soldiers of 6th Division reported ill
Mar.	Nieuwpoort	T- shells	Mixture of T- and B-stoff, 15-cm shells
22 Apr. (day)	Pilkem, north of Ypres	T- shells	Intense shelling of 45th Algerian Division with HE and T-stoff
22 Apr. (5 p.m.)	Bikschote, Poelkapelle, Langemark, Pilkem	Chlorine cloud, T-shells	150–168 tonnes chlorine gas released from almost 6000 cylinders along 700-metre front; T-shells fired with chlorine cloud
22 Apr. (dusk)	Steenstrate, north of Ypres	T- shells	Shelling with T-stoff (15-cm shells) of 6th Belgian Division defending against German attack on northern edge of Ypres salient
22 Apr. (dusk)	Boezinge	? T- shells	Artillery barrage of village, including gas shells
24 Apr. (2 a.m.)	Poelkapelle–St Juliaan, north-east of Ypres	Chlorine cloud	15 tonnes chlorine released on left flank of 2nd Canadian Division
24 Apr.	Lizerne, north of Ypres	T- shells	1200 T-shells fired to create gas wall (Gaswand) behind Belgian 6th Division to prevent reinforcements from reaching the front
24 Apr.	Boezinge	T- shells	Similar attack against troop concentrations in Boezinge Castle park
27 Apr.	Steenstrate–Lizerne	Chlorine cloud	German forces open northernmost gas cylinders, which had remained closed on 22 Apr. because of technical problems
29 Apr.	Steenstrate–Sas	Chlorine cloud	Small cylinder attack fails because of high winds and prompt retaliation by British artillery, which smashes many cylinders
1 May	Hill 60, south-east of Ypres	Chlorine cloud	60 cylinders opened against 1st Dorsets; casualties on both sides because of blowback
2 May	Ypres salient, British sector, ? south-west of Pilkem	Chlorine cloud	Attack against British 12th and 84th brigades[a]
5–6 May (night)	Hill 60	Chlorine cloud	Large number of cylinders released on 1400-metre front south of Hoge
10 May	Hill 60	Chlorine cloud	Small attack, few British casualties, probable release of remaining cylinders from 5–6 May attack

Date	Location	Type of attack	Comments
24 May (2:45 a.m.)	Frezenburg, east of Ypres	Chlorine cloud	Last gas discharge in Second Battle of Ypres from freshly installed cylinders; shells also used
16 Aug.	Belgian sector	B-stoff	Attack using 150-mm shells, presumably filled with bromacetone, against company of 1st Cycle Battalion near Noordschote (*c.* 10 km south of Diksmuide); last known gas attack against Belgian troops in 1915
19 Dec. (5:15 a.m.)	Wieltje, north-east of Ypres	Chlorine and phosgene cloud	First use of phosgene; 180 tonnes in 80 : 20 chlorine : phosgene ratio released from 9300 cylinders against British troops, who suffer relatively light casualties because of ample warning and 'gas discipline'
1916			
30 Apr. (12:35 a.m.)	Wulvergem, south of Ypres	Chlorine and phosgene cloud	Cloud launched on 3.2-km front; 512 British casualties, 89 of whom die
13 June	Ypres salient	Chlorine cloud	First British attack in Belgium; 300 cylinders opened along front of 20th Division
16 June (12:40 a.m.)	Wulvergem	Cloud gas, presumably chlorine	80% of 2000 large and 3000 small cylinders opened from German trenches
8 Aug.	Wieltje	Chlorine and phosgene cloud	Last German cloud gas discharge of the war against British troops; mixture contained higher percentage phosgene (50 : 50) than usual; 370 British troops killed, 434 injured; 174 casualties in 1st Canadian Division
29 Aug.	Steenstraat	. .	Attack on the Belgian front[b]
1 Sep.	Mesen (Messines), south of Ypres	Cloud gas	British discharge 118 cylinders; cloud drifts back into British trenches
5 Oct. (11 p.m.)	Nieuwpoort	White star cloud	British discharge 2050 cylinders; cloud affects civilians as far away as Raversijde, near Ostend
1917			
23 Apr.	Nieuwpoort	Chlorine cloud	Massive German cloud attack against French in Nieuwpoort spreads over entire Belgian front when wind turns unexpectedly; effects felt 43 km away; 1 Belgian killed, numerous casualties
4 May	Nieuwpoort, Diksmuide	. .	Attack on the Belgian front
24 May–7 June	Mesen–Wijtschate	Gas[c]	British Special Brigade conducts night gas attacks in preparation for attack on Mesen–Wijtschate Ridge on 7 June; additional 4700 cylinders, 4800 projector drums and 4250, 4-inch bombs containing 300 tonnes gas readied but not discharged because of weather

Date	Location	Type of attack	Comments
29 May	Mesen–Wijtschate	Phosgene projector drums, mortar bombs	700 projector drums and 1000, 4-inch bombs fired
1 June	Mesen–Wijtschate	Phosgene projector drums	900 projector drums fired
2 June	Mesen–Wijtschate	Phosgene projector drums	100 projector drums fired
2–5 June	Nieuwpoort	Various agents	Daily attacks on the Belgian front
3 June	Wijtschate Wood, Grand Bois, unnamed wood	Oil drums, mortar bombs	1500 oil drums and 1000 bombs fired from Stokes mortars
4 June	Mesen	Oil drums	1500 oil drums fired at woods on Mesen Ridge
6 June	Ramskapelle, Pervijze	. .	Attack on the Belgian front
7 June	Mesen–Wijtschate	CBR, PS and SK shells, white phosphorus and thermit bombs	30-minute artillery barrage at zero hour; 450 white phosphorus and 300 thermit bombs fired during infantry advance
7 June	Ploegsteert Wood, south of Mesen	Phosgene shells, tear gas	German artillery barrage on 3rd Australian Division while taking assault positions
7 June	Nieuwpoort	Chlorine cloud	Release of chlorine gas cloud against French forces; 120 casualties in 1 hospital[d]
8 June	Boezinge	Gas bombs	50 British 120-kg heavy gas bombs fired on village[e]
20–21 June (night)	Hoge, east of Ypres	Gas	British attack, large number of gas casualties in 46th German Regiment
6–10 July	Nieuwpoort	Green cross, lachrymator, Blue cross (DA)	Heavy artillery bombardment of British troops, high percentage of gas shells; 10 July, 1st use of DA shells
12 July	Oothof	. .	Attack on the Belgian front
12–13 July	St Jan–Potijze, north-east of Ypres	Phosgene, Yellow cross	Heavy pre-emptive artillery bombardment of British 15th and 55th divisions before Third Battle of Ypres; 1st use of mustard gas, 50 000 shells fired
13 July (night)	Ypres area	Projector	British Livens projector attack
15 July	Bellewaarde Lake, near Hoge	Gas	German gas attack on British trenches
15–21 July	Ypres salient	Projector and mortar	British fire 5100 projector drums and 14 000 Stokes mortar bombs (100 tonnes gas) in preparation for Third Battle of Ypres
16 July	Langemark	Gas	British gas attack on 226th Reserve Regiment
20 July (night)	Boezinge	Projector	British Livens projector attack

Date	Location	Type of attack	Comments
20–21 July (night)	Near Ypres, Wijschate	Blue cross	German use of DA (repeated several nights later); British find unexploded blue cross shells near Wijtschate on 28 July
21 July	Pildem, Boezinge	Gas mines	British gas attack kills 150 in German 102nd Reserve Regiment
21 July (2 a.m.)	Langemark	Projector	British gas attack on German 392nd Regiment
21–22 July (night)	Nieuwpoort	Yellow cross	2821 British casualties, including 17 dead
23 July	Nieuwkapelle, Hazewind, Diksmuide	. .	Attack on the Belgian front
24 July	Hazewind, Diksmuide	. .	Attack on the Belgian front
25 July	Nieuwpoort	. .	Attack on the Belgian front
26 July	Nieuwkapelle, Hazewind, Diksmuide	. .	Attack on the Belgian front
End July–mid-Aug.	Ypres salient	Yellow cross	Systematic night attacks on British positions, including targets in the rear
28 July (night)	Nieuwpoort	Yellow cross	Heavy German artillery attack
28–30 July	Ypres salient	Phosgene, chloropicrin, stannic chloride	British counter-battery fire using large variety of gas shells; 80 000 shells reportedly fired
29 July	Kouseboom	. .	Attack on the Belgian front
31 July (3:50 a.m.)	Ypres salient	Oil drums, thermit	British fire 330 oil drums and 1300 thermit bombs at start of Third Battle of Ypres
5–17 Aug.	Ramskapelle	. .	Several attacks on the Belgian front
22 Aug.	Hazewind, Diksmuide	. .	Attack on the Belgian front
7 Sep.	Hazewind, Diksmuide	. .	Attack on the Belgian front
11 Sep.	Hazewind, Diksmuide	. .	Attack on the Belgian front
18 Sep.	Langemark	Projector	Many casualties in all 3 regiments of 36th German Division
25 Sep.	Hazewind, Diksmuide	. .	Attack on the Belgian front
27 Sep.	Warneton, south of Ypres, near French border	Phosgene	British drum attack, many German casualties
7 Oct.	Ramskapelle	. .	Attack on the Belgian front
9 Oct.	Ypres	. .	Attack on the Belgian front
16 Oct.	Poelkapelle, Passendale	. .	Attack on the Belgian front
19–20 Oct. (night)	Poelkapelle	Projector and mortar	136 drums fired on Meunier House and 285, 4-inch bombs fired at Poelkapelle Brewery

Date	Location	Type of attack	Comments
26–27 Oct.	Diksmuide	Gas cloud, projectors, mortars, flame projectors	British attack from Belgian trenches in quiet sector to support operations in Ypres salient; integrated attack with gas cloud, 200 CG bombs and 150 thermit bombs fired from Stokes mortars
29 Oct. (night)	Diksmuide	Projector	1480 projector drums fired at targets 0.8 km south of Diksmuide
31 Oct.	Hazewind, Diksmuide	. .	German attack on the Belgian front
End Oct. or early Nov.	Nieuwpoort, Diksmuide	Shells	1st Belgian chemical attacks retaliate against German shelling with gas
1 Nov.	Oostkerke	. .	German attack on the Belgian front
2–5 Nov.	Passendale, Oostkerke, Nieuwpoort, Diksmuide	. .	German attack on the Belgian front
2 Nov.	Diksmuide	SK	400 SK bombs fired at German heavy trench mortar battery in Diksmuide
6 Nov.	Diksmuide	Projector	960 projector drums fired
7 Nov.	Pervijze, Oostkerke, Nieuwkapelle, (? Diksmuide)	Mustard gas shells	1st mustard gas attacks on Belgian positions
9 Nov.	Diksmuide	Mortar	40 mortars fire 1530 bombs on town
12–15 Nov.	Passendale, Oostkerke, Nieuwpoort, Diksmuide	. .	Attack on the Belgian front
20 Nov.	Passendale, Oostkerke, Nieuwpoort, Diksmuide	. .	Attack on the Belgian front
21 Nov.	Oostkerke	. .	Attack on the Belgian front
17 Dec.	Merkem	. .	Attack on the Belgian front
18 Dec.	Merkem	. .	Attack on the Belgian front
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18 Feb.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
22 Feb.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
24 Feb.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
25 Feb.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
26 Feb.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
3 Mar.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
5–22 Mar.	Nieuwpoort, Boezinge	. .	Attack on the Belgian front
11–15 Mar.	Ypres salient	Yellow, green and blue cross	Heavy German shelling with mustard gas; green and blue cross directed at strong points and headquarters
17–23 Mar.	Ramskapelle	. .	Attack on the Belgian front
18 Mar.	Diksmuide, Pervijze	. .	Attack on the Belgian Front
21 Mar.	Pervijze	. .	Attack on the Belgian Front
27 Mar.	Nieuwpoort, Boezinge	. .	Attack on the Belgian Front
28–30 Mar.	Ramskapelle	. .	Attack on the Belgian front
3 Apr.	Ramskapelle	. .	Attack on the Belgian front

Date	Location	Type of attack	Comments
4 Apr.	Ramskapelle	. .	Attack on the Belgian front
8–12 Apr.	Ramskapelle Nieuwpoort	. .	Attack on the Belgian front
9–25 Apr.	Kemmelberg, south-west of Ypres	Yellow, green and blue cross	Battle for Mount Kemmel
16 Apr.	Ramskapelle	. .	Attack on the Belgian front
17 Apr.	Ramskapelle	. .	Attack on the Belgian front
24 Apr.	Ramskapelle	. .	Attack on the Belgian front
25 Apr.	Ramskapelle	. .	Attack on the Belgian front
25 Apr.	Kemmelberg	Yellow, green and blue cross[f]	Barrage intended to isolate French troops during final assault
27 Apr.	Boezinge, Langemark	. .	Attack on the Belgian front
3 May	Nieuwpoort, Boezinge, Langemark	. .	Attack on the Belgian front
5 May	Boezinge	. .	Attack on the Belgian front
9 May	Merkem	. .	Attack on the Belgian front
10 May	Boezinge, Langemark	. .	Attack on the Belgian front
14–18 May	Nieuwpoort	. .	Attack on the Belgian front
2 June	Nieuwpoort	. .	Attack on the Belgian front
3 June	Nieuwpoort	. .	Attack on the Belgian front
6 June	Nieuwpoort, Ramskapelle, Pervijze	. .	Attack on the Belgian front
8 June	Nieuwpoort	. .	Attack on the Belgian front
22 June. (night)	Ypres salient	Gas cloud	Beam attack form railway trains against 31st German Division causing 500 casualties
23 June	Oostduinkerke	. .	Attack on the Belgian front
12 July	Oothof	. .	Attack on the Belgian front
24 July	Ypres salient	Gas cloud	Beam attack from railway trains against 1st Landwehr Division, which was withdrawn because of severe casualties
20 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
21 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
22 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
23 Aug.	Nieuwpoort	. .	Attack on the Belgian front
24 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
26 Aug.	Ypres salient	Gas cloud	Bean attack from railway trains
26 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
30 Aug.	Steenstrate, Boezinge	. .	Attack on the Belgian front
11 Sep.	Ypres salient	Projector	British launch 580 projector drums
12 Sep.	Nieuwpoort	. .	Attack on the Belgian front
15 Sep.	Nieuwpoort	. .	Attack on the Belgian front

Date	Location	Type of attack	Comments
1–14 Oct.	Staden, Nieuwpoort, Pervijze, Moorslede, Diksmuide	. .	Attack on the Belgian front
13–14 Oct.	Wervik	HS shells	More than 1000 HS shells fired; attack during which Adolf Hitler was gassed
17 Oct.	Loppem	. .	Attack on the Belgian front
22 Oct.	Zomergem	. .	Attack on the Belgian front
23 Oct.	Bellem	. .	Attack on the Belgian front
27–28 Oct.	Avelgem	Yellow cross	500 rounds fired, gassing at least 350 civilians
30 Oct.	Zomergem	. .	Attack on the Belgian front
Early Nov.	Hansbeke	Yellow cross	27 civilians reported dead
2 Nov.	Tournai Wood	Gas drum	British fired 50 gas drums
8 Nov.	Bossuit, north of Tournai	Thermit bombs	252 thermit bombs fired in last attack of the war by British Special Brigade

T-stoff = German code-name for liquid lachrymatory, mix of brominated aromatic hydrocarbons, filled in lead canisters; B-stoff = German code-name for bromoacetone; HE = High explosive; CBR = British designation for 50% phosgene and 50% arsenic chloride; PS = British designation for chloropicrin; SK = British designation for ethyl iodoacetate; DA = Diphenylchloroarsine; CG = Phosgene; HS = British code-name for bis(2-chloroethyl) sulphide (i.e., mustard gas). (For a discussion of the cross codes, see the subsection 'Colour coding using cross codes' in section II of chapter 6 in this volume.)

[a] In *The Poisonous Cloud: Chemical Warfare in the First World War* (Clarendon Press: Oxford, 1986), L. F. Haber disputes claims that a German attack occurred on that day, based on lack of documentary evidence in British or German archives. However, the 29 June 1915 *London Gazette*—reproduced in Latter, J. C. (Maj.-Gen.), *The History of the Lancashire Fusiliers, 1914–1918 in Two Volumes* (Gale & Polden: Aldershot, 1949)—reports the awarding of the Victoria Cross to Private J. Lynn of the 2nd Lancashire Fusiliers, who 'handled his machine-gun with very great effect against the enemy' who were 'advancing behind their wave of asphyxiating gas'. Lynn died the following day of gas poisoning.

[b] All references to 'attack on the Belgian front' are from annexe P of Lheureux, V. (2nd Lt.), 'L'utilisation des gaz de combat sur le front belge pendant la guerre 1914–1918' [Use of gas on the Belgian front in the 1914–18 war], and its annexes, Travail de fin d'études présenté pour l'obtention du titre de licencié en Sciences Sociales et Militaires, Ecole Royale Militaire, 126e Promotion Toutes Armes, 1989–90 [Dissertation submitted to obtain the degree of master in social and military sciences, Royal Military Academy, 126th Promotion All Arms, 1989–90]. Lheureux's compilation is based on documents from the Belgian Armed Forces and on weekly communiqués issued by Belgian General Headquarters. The compilation is the only known study of chemical warfare operations against and by Belgian troops which uses source documents; it does not detail the origin or nature of the attacks.

[c] Specifics of the most important attacks are given in the following entries.

[d] Mentioned in Foulkes, C. H., *'Gas!': The Story of the Special Brigade* (William Blackwood & Sons: Edinburgh and London, 1936, 2nd reprint), p. 117, without specifying how the gas clouds were generated.

[e] Baccarne, R. and Steen, J., *Boezinge 1914–1918: Gasaanval 2° Slag om Ieper* [Boezinge 1914–18: gas attack at the Second Battle of Ypres] (Uitgegeven onder de auspiciën van de N. V. Bank van Roeselare en West Vlaanderen [Published under the auspices of the N. V. Bank van Roeselare en West Vlaanderen], 1979), p. 135 (in Dutch), states that the bombs were filled with chlorine and sulphur dioxide.

[f] Yellow cross was used near Ypres, Verbrande Molen (south of Zillebeke Vijver), Hoge (north of Zillebeke Vijver) and on a narrow stretch running south-west by north-east from Scherpenberg (1.5 km north of Loker) and east from Dikkebusch Vijver to approximately 3.5 km south-west of Ypres. Green cross was used west, north and east of Reningelst. Blue cross was used in the attack on 2 French divisions in trenches stretching from south of Kemmelberg to an area between Kemmel and Wijtschate.

Sources: Baccarne, R. and Steen, J., *Boezinge 1914–1918: Gasaanval 2° Slag om Ieper* [Boezinge 1914–18: gas attack at the Second Battle of Ypres] (Uitgegeven onder de auspiciën N. V. Bank van Roeselare enWest Vlaanderen [Published under the auspices of the N. V. Bank van Roeselaere en West Vlaanderen], 1979) (in Dutch); Breton, W., *Les combats de Steenstraat Avril–Mai 1915* [The Battle of Steenstraat, April–May 1915] (Librairie Militaire Berger–Levrault: Paris, 1918); Delfosse, *Les grenadiers à Steenstraat/De grenadiers te Steenstraat* [The grenadiers at Steenstraat] (Ets. L. Collignon: Brussels, 1934); Edmonds, J. E. (Brig.-Gen.) and Becke, A. F. (Maj.), *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1915*, vol. 2 (MacMillan: London, 1928); Edmonds, J. E. (Brig.-Gen.) and Becke, A. F. (Maj.), *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1916*, vol. 1 (MacMillan: London, 1932); Edmonds, J. E. (Brig. Gen.) and Litt, D., *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1917*, vol. 2. (MacMillan: London, 1948); Edmonds, J. E. (Brig.-Gen.) and Litt, D., *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1918*, vol. 4 (His Majesty's Stationery Office: London, 1947); Edmonds, J. E. (Brig.-Gen.), Litt, D. and Maxwell-Hyslop, R., *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1918*, vol. 5 (His Majesty's Stationery Office: London, 1947); Edmonds, J. E. (Brig.-Gen.), Wynne, G. C. (Capt.) and Becke, A. F. (Maj.), *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1915* (MacMillan: London, 1927); Falls, C. and Becke, A. F. (Maj.), *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1917*, vol. 1 (MacMillan: London, 1940); Foulkes, C. H., *'Gas!': The Story of the Special Brigade* (William Blackwood & Sons: Edinburgh and London, 1936, 2nd reprint); Haber, L. F., *The Poisonous Cloud: Chemical Warfare in the First World War* (Clarendon Press: Oxford, 1986); Hanslian, R. and Bergendorff, F., *Der Chemische Krieg. Gasangriff, Gasabwehr und Raucherzeugung* [Chemical warfare: gas attack, gas defence and smoke generation] (E. S. Mittler & Sohn: Berlin, 1925); Lheureux, V. (2nd Lt.), 'L'utilisation des gaz de combat sur le front belge pendant la guerre 1914–1918' [Use of gas on the Belgian front in the 1914–18 war], and its annexes, Travail de fin d'études présenté pour l'obtention du titre de licencié en Sciences Sociales et Militaires, Ecole Royale Militaire, 126e Promotion Toutes Armes, 1989–90 [Dissertation submitted to obtain the degree of master in social and military sciences, Royal Military Academy, 126th Promotion All Arms, 1989–90]; Miles, W. and Becke, A. F. (Maj.), *History of the Great War Based on Official Documents: Military Operations, France and Belgium, 1916*, vol. 2 (MacMillan: London, 1938); Moore, W., *Gas Attack! Chemical Warfare 1915–18 and Afterwards* (Leo Cooper: London, 1987); and Latter, J. C. (Maj.-Gen.), *The History of the Lancashire Fusiliers 1914–1918 in Two Volumes* (Gale & Polden: Aldershot, 1949).