

Contents

<i>Preface</i>	xiii
<i>Contributors</i>	xv
<i>Acronyms and abbreviations</i>	xvii
Part I. Introduction to the problem	
1. Introduction	3
<i>Thomas Stock and Karlheinz Lohs</i>	
I. The scope of the problem	3
II. Definitions	7
III. The focus of the study	8
Part II. Chemical warfare agents and munition and toxic armament wastes	
2. Characteristics of chemical warfare agents and toxic armament wastes	15
<i>Karlheinz Lohs and Thomas Stock</i>	
I. Introduction	15
II. Chemical and toxicological properties of chemical warfare agents	16
III. Military smoke agents	28
IV. Toxic armament wastes	33
Table 2.1. Properties of organoarsenic chemical warfare agents	21
Table 2.2. Comparative data on phosgene and diphosgene	23
Table 2.3. Properties of hydrogen cyanide and cyanogen chloride	24
Table 2.4. Properties of selected riot control agents	25
Table 2.5. Physicochemical properties of nerve agents	26
Table 2.6. Estimates of toxicity of nerve agents to humans	27
Table 2.7. Clinical effects of nerve agents in humans	27
Figure 2.1. Metabolic pathways of sulphur mustard	18
Figure 2.2. The hydrolysis of lewisite	20
Figure 2.3. Neurotoxic effects of nerve gas exposure	28
3. Old chemical munitions and warfare agents: detoxification and degradation	35
<i>Thomas Stock and Karlheinz Lohs</i>	
I. Introduction	35
II. Deterioration of old chemical munitions	35
III. Detoxification and degradation of chemical warfare agents	45
IV. Conclusions	52
Table 3.1. Chemical warfare agents used in World War I and later	36
Table 3.2. Shell designation and code- or camouflage names of World War I chemical munitions	38
Table 3.3. Acronyms and code-names used for some chemical warfare agents in World War II	42
Table 3.4. Solubility of chemical warfare agents	46
Table 3.5. Half-life of sarin in water	48
Table 3.6. Stability of chemical warfare agents in fresh water	49
Table 3.7. Persistency of chemical warfare agents	51
Table 3.8. Stability in storage and corrosive action of chemical warfare agents	52

Part III. Coping with old munitions and toxic armament wastes: technical experience

4. Decontamination of former military bases in eastern Germany 55

Karl Lehmann and Reiner Escher

I.	Introduction	55
II.	Areas of potential contamination	57
III.	Treatment of hazardous waste sites	58
IV.	Decontamination activities and findings	60
V.	Hazardous military waste and its conversion	63
Table 4.1.	Typical functions and services available on WGT bases	57
Table 4.2.	Types of hazardous waste likely to be found on a military base	58
Figure 4.1.	Distribution of former WGT bases in the new federal states and Berlin, as of July 1992	56
Figure 4.2.	Distribution by size of the former WGT bases in eastern Germany, as of July 1990	56
Figure 4.3.	Contamination of the solid by mineral oil hydrocarbons on former WGT bases	61
Figure 4.4.	Contamination of the soil by mineral oil hydrocarbons at a filling station with a ground-water level of three metres	62
Figure 4.5.	Contamination of the soil by mineral oil hydrocarbons at a fuel depot with a ground-water level of three metres	63

5. Decontamination of the Wehrmacht gas laboratory at Spandau Citadel, Berlin: technical and organizational experiences 65

Wolfgang P. W. Spyra

I.	Introduction	65
II.	Research	66
III.	The decontamination strategy	67
IV.	Hazards	68
V.	Basic considerations	69
VI.	Safety precautions	70
VII.	Securing the site on a daily basis	73
VIII.	Conclusions	73
Figure 5.1.	Chemical decontamination activities at Spandau Citadel	67

Part IV. Chemical weapons: past production activities

6. The production of chemical warfare agents by the Third Reich, 1933–45 77

Bernd Appler

I.	German chemical warfare agent armament, 1919–45	77
II.	Production of chemical warfare agents in the Third Reich, 1933–45	78
III.	The status of chemical warfare agents at the end of World War II	94
IV.	Chemical warfare agents as toxic armament wastes	97
Table 6.1.	List referred to in the letter of 6 August 1942, from the Army Ordnance Department to Minister of Armament and Ammunition Albert Speer	83
Table 6.2.	Requests from the General Staff for sulphur mustard	84
Table 6.3.	Plants which the German Government ordered to be built for the production of chemical warfare agents	85

Table 6.4.	Plants for the production of chemical warfare agents that were built but which never functioned	85
Table 6.5.	Production of chemical warfare agents during the Third Reich	86
Table 6.6.	The quantities of chemical warfare agents requested by the General Staff as of 1 April 1944, and the amounts of these agents which existed at that time	87
Table 6.7.	A partial list of the colour-coding system for German CW munitions in World War II	88
Table 6.8.	Mustard agents and mixtures used to fill munitions during the Third Reich	89
Table 6.9.	The effectiveness of chemical warfare agents in 15-cm shells	93
Table 6.10.	The effectiveness of chemical warfare agents in the KC 250 bomb	93
Table 6.11.	Actual and estimated inventory of munitions filled with chemical warfare agents as of 1 April 1944	95
Table 6.12.	Munitions filled with chemical warfare agents captured by the Allies	96
Figure 6.1.	Location of German plants which produced chemical warfare agents before and during World War II	81
Figure 6.2.	Organization of the Army Proving Ground (Heeresversuchsstelle Raubkammer) at Munster, Germany	91
Figure 6.3.	The Army Proving Ground (Heeresversuchsstelle Raubkammer) at Munster, Germany	92
Appendix 6A.	A chronology of German research, development and preparation for chemical warfare agent production	99
Appendix 6B.	German plants that produced chemical warfare agents and their total production output	101
Table 6B.1.	Production of sulphur mustard and nitrogen mustard at Halle Ammendorf	102
7. Chemical weapon production in the former Czechoslovakia		104
<i>Jirí Matousek</i>		
I.	Introduction	104
II.	The development of chemical defence and retaliatory potential	105
III.	Chemical defence institutions and preparation for the use of chemicals in war	107
IV.	Destruction and disposal of chemical weapons	110
V.	Conclusions	111
8. The history of chemical weapons in Poland		112
<i>Zygfryd Witkiewicz and Kazimierz Szarski</i>		
I.	Introduction	112
II.	The use of chemical weapons in World War I	112
III.	The interwar period	113
IV.	Research activities	114
V.	Manufacturing activities	115
VI.	World War II	115
VII.	The post-World War II period	117
VIII.	The remaining CW stockpile	117
IX.	Chemical weapons in the Baltic Sea	119
X.	Conclusions	120

9. Chemical munitions in the Commonwealth of Independent States and the surrounding seas 121*Judith Perera*

I.	Introduction	121
II.	Chemical weapon stockpiles	121
III.	Chemical weapon production	124
IV.	Storage depots	128
V.	Environmental contamination on land	129
VI.	Dumping at sea	132
VII.	Chemical weapon destruction	134
VIII.	Conclusions	136
Table 9.1.	Chemical weapon production from before World War II to 1987	123
Table 9.2.	Main chemical weapon facilities during World War II	125
Table 9.3.	Postwar chemical weapon facilities	127
Table 9.4.	Distribution of chemical weapon stockpile by storage mode	129
Table 9.5.	Russian storage depots	130
Table 9.6.	Proposed deadlines for destruction of the Russian chemical weapon stockpile	135

Part V. Chemical weapon disposal and destruction**10. The destruction of old and obsolete chemical weapons: past experience** 141*Ronald G. Sutherland*

I.	Introduction	141
II.	Chemical destruction technology	141
Table 10.1.	Summary of the experience of the US Army in industrial-scale chemical agent/munition disposal, 1974–91	148
Table 10.2.	Experience in the destruction of chemical weapons	153

11. The technical challenge of dismantling and destroying old and abandoned chemical weapons 156*Frédéric Guir*

I.	Introduction	156
II.	The scope of the task	156
III.	A proposed universal solution: the firing pool	161
IV.	The destruction process	163
V.	Conclusions	165
Table 11.1.	Quantities of chemical warfare agents produced by France and Germany in World War I	160
Table 11.2.	Total quantity of chemical weapon-filled shells fired in World War I	161
Table 11.3.	Quantity of chemical weapon-filled shells delivered to the Allied forces by France in World War I	161

12. The German programme for the disposal of old chemical weapons 166*Hermann Martens*

I.	Introduction	166
II.	Types of OCW munitions and chemical fills	166
III.	Steps for disposing of old chemical weapons	167
IV.	Destruction of chemical agents	170
V.	The incineration plant	170
VI.	Operational data	175
VII.	Control of emissions	177

VIII.	The disposal balance of the incineration plant	177
IX.	Cost considerations	177
X.	Conclusions	178
Table 12.1	Operational data for the Munster incineration plant, as of March 1993	176
Table 12.2	Waste air and waste water data for the Munster incineration plant, as of March 1993	176
Table 12.3	Disposal balance for the Munster incineration plant, as of March 1993	177
Table 12.4	Cost for operation of the Munster incineration plant, as of March 1993	178
Figure 12.1.	Composition of the clumps of viscous mustard gas	171
Figure 12.2.	Functional diagram of the Munster incineration plant	172
Figure 12.3.	The main combustion chamber	173
Figure 12.4.	Destruction of chemical warfare agents	174
Figure 12.5.	Flue gas scrubbing	174
Figure 12.6.	Destruction of chemical warfare agents, arsenic precipitation	175
13. Postwar destruction of chemical weapons in the former German Democratic Republic		179
<i>Karlheinz Lohs</i>		
I.	Introduction	179
II.	The postwar situation in the former German Democratic Republic	180
III.	Destruction activities at Kapen	180
IV.	Special problems	181
V.	Other munition sites and activities	182
VI.	The status of destruction in 1962	183
VII.	Nerve agents	184
VIII.	Smoke-producing agents and obscurants	185
IX.	The status of destruction: 1962-89	186
X.	Conclusions	186
14. The storage of old and abandoned chemical weapons in Austria		187
<i>Josef Stolz</i>		
I.	Old and abandoned CW munitions in Austria	187
II.	Protecting the environment from the CW munitions	191
III.	Recently discovered CW munitions	193
IV.	The recovery and disposal of CW munitions in Austria	194
V.	Conclusions	195
Figure 14.1.	The hydrolysis of Nitrogen-Lost	194
15. The destruction of old chemical munitions in Belgium		197
<i>Jean Pascal Zanders</i>		
I.	Chemical warfare in Belgium in World War I	197
II.	Early disposal of old chemical munitions	201
III.	Belgian chemical weapon production	207
IV.	Sea dumping of old chemical munitions	208
V.	Description of the stock of old chemical munitions	211
VI.	The dismantling facility: a brief overview of the policy-making process	215
VII.	The dismantling facility: a brief overview of planned procedures	219
Table 15.1.	Pickett et Fils production rates (explosive and chemical munitions)	205
Table 15.2.	The evolution of the stocks of toxic munitions, 1980-96	212

x CHALLENGE OF OLD CHEMICAL MUNITIONS

Table 15.3.	Summary of munitions at Poelkapelle	214
Figure 15.1.	Procedures in the identification building	220
Figure 15.2.	Procedures in the dismantling building	221
Figure 15.3.	Procedures in the decontamination building	222
Appendix 15A.	Chemical attacks on the Belgian front, 1915–18	223

16. Chemical weapon agent and historic chemical munitions disposal: the British experience

Ron G. Manley

I.	Introduction	231
II.	Disposal options	232
III.	Disposal of bulk CW stocks	233
IV.	Decontamination and disposal of the GB pilot plant	234
V.	Disposal of historic chemical munitions	235
VI.	Safety and environmental aspects	239
VII.	Conclusions	240
Figure 16.1.	Principal components of the Chemical & Biological Defence Establishment's hazardous waste incinerator	237

17. UNSCOM's experience with chemical warfare agents and munitions in Iraq

Ron G. Manley

I.	Introduction	241
II.	Iraq's CW agents and munitions	241
III.	CW production facilities	242
IV.	Planning the disposal of Iraq's chemical weapons	243
V.	Safety and environmental considerations	244
VI.	Transportation, draining and destruction of munitions	244
VII.	Hydrolysis of the bulk nerve agent	246
VIII.	Incineration of mustard gas	248
IX.	Disposal of 122-mm nerve agent rockets	249
X.	Disposal of CW agent precursors	250
XI.	Destruction of production facilities	251
XII.	Completion of CW destruction operations	251
XIII.	Future compliance monitoring	251
Table 17.1.	The target emission standards for the incineration plant at Al Muthanna	249

Part VI. Sea dumping of chemical weapons

18. Legal problems related to old chemical munitions dumped in the Baltic Sea

Hans-Joachim Heintze

I.	Introduction	255
II.	International law and old, dumped chemical munitions	256
III.	International law and dumping at sea	257
IV.	The Helsinki Convention	259
V.	Conclusions	262

19. The Baltic and North Sea dumping of chemical weapons: still a threat?

Fredrik Laurin

I.	Introduction	263
II.	Historical overview	266
III.	Conclusions	275

Table 19.1.	Known dumping sites in and near Scandinavia	264
Figure 19.1.	Sites of chemical munition dumping after World War II	266
20. Investigation of the ships filled with chemical munitions which were sunk off the Norwegian coast after World War II		279
<i>Frode Fonnum</i>		
I.	Introduction	279
II.	Information from British sources	279
III.	Norwegian information	281
IV.	US reports	283
V.	The Norwegian investigation	284
VI.	Analysis of the data	287
Table 20.1.	List of ships scuttled in the sea provided by Einar Høvding	282
Table 20.2.	Positions of ships sunk in Operation 'Davey Jones Locker', 1946	283
Table 20.3.	Positions of ships sunk in Operation 'Davey Jones Locker', June 1947–Aug. 1948	284
Table 20.4.	Positions of wrecks identified by sidescan sonar in the Norwegian Trench	285
Figure 20.1.	Positions of the shipwrecks as determined by the use of sidescan sonar, a Trisponder navigation chain and Decca	286
Part VII. Legal issues		
21. The Chemical Weapons Convention and old and abandoned chemical weapons		293
<i>Thomas Stock</i>		
I.	Introduction	293
II.	The CWC provisions on old and abandoned chemical weapons	294
III.	Chemical weapons buried or dumped at sea	297
IV.	Provisions of the CWC related to former CW production facilities	297
V.	Provisions for declaration, identification, verification and destruction of old and abandoned chemical weapons	298
VI.	The function of the Preparation Commission	301
VII.	The role of the individual State Party	304
VIII.	Destruction technology	305
XVII.	Conclusions	306
Table 21.1.	Obligations and definitions related to old and abandoned chemical weapons for parties to the Chemical Weapons Convention	296
Table 21.2.	Technologies for the destruction of chemical agents	306
22. The legal problems associated with sites contaminated by chemical warfare agents in Germany		308
<i>Thomas Kurzidem</i>		
I.	Introduction	308
II.	Defining the problem	309
III.	German environmental law and sites contaminated by old armament wastes	311
IV.	Responsibility and liability for environmental damage	316
V.	Legislative initiatives of the states related to sites contaminated by old armament wastes and contaminated military sites	321
VI.	Military forces and German environmental law	323
VII.	Conclusions	326

Part VIII. Final discussion and recommendations

23. Conclusions 329

Thomas Stock and Karlheinz Lohs

I. Introduction 329

II. Major findings of the study 330

SIPRI publications on CBW 336