

**POTENTIAL FOR SURFACE CONTAMINATION
BY DEPOSITION OF CHEMICAL AGENT
FOLLOWING ACCIDENTAL RELEASE
AT AN ARMY STORAGE DEPOT**

Volume 1: Chemical Agent Deposition Study

Decision and Information
Sciences Division
Argonne National Laboratory

Operated by The University of Chicago, under Contract W-31-
109-Eng-38, for the

United States Department of Energy

CONTENTS

FOREWORD	iii
ACKNOWLEDGMENTS	xii
ABSTRACT	1
1 INTRODUCTION	1
1.1 Purpose and Scope	1
1.2 Background	2
1.3 Approach	4
1.4 Report Organization	6
2 CHEMICAL AGENTS AND CHEMICAL MUNITIONS	8
2.1 Chemical Agents and Munitions	8
2.1.1 Nerve Agents	8
2.1.2 Blister Agents	9
2.1.3 Composition of the Chemical Stockpile	10
2.2 Chemical Munitions Storage and Processing	11
3 CHEMICAL STORAGE DEPOTS	13
3.1 Aberdeen Proving Ground	17
3.2 Anniston Army Depot	20
3.3 Blue Grass Army Depot	26
3.4 Newport Army Ammunition Plant	32
3.5 Pine Bluff Arsenal	35
3.6 Pueblo Depot Activity	41
3.7 Tooele Army Depot	46
3.8 Umatilla Depot Activity	52
4 CLOUD TRANSPORT AND DIFFUSION MODEL	58
5 PARAMETRIC MODEL STUDY OF AGENT DEPOSITION	63
5.1 Parameters and Parameter Values Used in the Study	63
5.2 Results of the Parametric Study	71
5.3 Interpretation of Results	82
6 AGENT DEPOSITION THROUGH VAPOR CONDENSATION	84
7 OTHER POTENTIAL INFLUENCES ON AGENT DEPOSITION PATTERNS	90

8	SUMMARY AND CONCLUSIONS	93
	REFERENCES	94
	APPENDIX A: Potential for Deposition of Agent GB Beyond a Depot Boundary	97
	APPENDIX B: Vapor Pressure and Volatility of Chemical Agents	101
	APPENDIX C: Estimation of the Cloud Volume	103
	APPENDIX D: Estimated Upper Bounds of the Downwind Extent of Agent Deposition Patterns	109

TABLES

1.1	Summary of Report Sections and Their Contents	7
2.1	Physical Properties of Selected Nerve Agents	9
2.2	Physical Properties of Selected Blister Agents	10
2.3	Chemical Munitions/Containers	11
3.1	Distances to Depot Boundaries	16
3.2	Selected Release Scenarios Associated with the Storage Facility at Aberdeen Proving Ground	19
3.3	Selected Release Scenarios Associated with the Demilitarization Facility at Aberdeen Proving Ground	19
3.4	Chemical Munitions and Chemical Agents Stored at Anniston Army Depot	20
3.5	Selected Release Scenarios Associated with the Storage Facility at Anniston Army Depot	23
3.6	Selected Release Scenarios Associated with On-Site Transportation at Anniston Army Depot	24
3.7	Selected Release Scenarios Associated with the Demilitarization Facility at Anniston Army Depot	25
3.8	Chemical Munitions and Chemical Agents Stored at Blue Grass Army Depot	26

TABLES (Cont'd)

3.9	Selected Release Scenarios Associated with the Storage Facility at Blue Grass Army Depot	29
3.10	Selected Release Scenarios Associated with On-Site Transportation at Blue Grass Army Depot	30
3.11	Selected Release Scenarios Associated with the Demilitarization Facility at Blue Grass Army Depot	31
3.12	Selected Release Scenarios Associated with the Storage Facility at Newport Army Ammunition Plant	34
3.13	Selected Release Scenarios Associated with the Demilitarization Facility at Newport Army Ammunition Plant	34
3.14	Chemical Munitions and Chemical Agents Stored at Pine Bluff Arsenal	35
3.15	Selected Release Scenarios Associated with the Storage Facility at Pine Bluff Arsenal	38
3.16	Selected Release Scenarios Associated with On-Site Transportation at Pine Bluff Arsenal	39
3.17	Selected Release Scenarios Associated with the Demilitarization Facility at Pine Bluff Arsenal	40
3.18	Chemical Munitions and Chemical Agents Stored at Pueblo Depot Activity	41
3.19	Selected Release Scenarios Associated with the Storage Facility at Pueblo Depot Activity	44
3.20	Selected Release Scenarios Associated with On-Site Transportation at Pueblo Depot Activity	44
3.21	Selected Release Scenarios Associated with the Demilitarization Facility at Pueblo Depot Activity	45
3.22	Chemical Munitions and Chemical Agents Stored at Tooele Army Depot	46
3.23	Selected Release Scenarios Associated with the Storage Facility at Tooele Army Depot	49
3.24	Selected Release Scenarios Associated with On-Site Transportation at Tooele Army Depot	50

TABLES (Cont'd)

3.25 Selected Release Scenarios Associated with the Demilitarization Facility at Tooele Army Depot	51
3.26 Chemical Agents and Chemical Munitions Stored at Umatilla Depot Activity	52
3.27 Selected Release Scenarios Associated with the Storage Facility at Umatilla Depot Activity	55
3.28 Selected Release Scenarios Associated with On-Site Transportation at Umatilla Depot Activity	56
3.29 Selected Release Scenarios Associated with the Demilitarization Facility at Umatilla Depot Activity	57
4.1 Assumptions of the GAPCAP Model as Used in the Present Study	61
4.2 Input Parameters of the GAPCAP Model	62
5.1 Deposition Velocities	64
5.2 Atmospheric Diffusion Parameter Values from the D2PC Model	66
5.3 Average Mixing-Layer Heights	67
5.4 Parameters and Parameter Values for Model Study	67
5.5 Wind Speed Restrictions	68
5.6 Full Width of the Predicted Agent Deposition Pattern for 100 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category B and a 3 m/s Wind Speed	79
5.7 Full Width of the Predicted Agent Deposition Pattern for 100 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category D and a 3 m/s Wind Speed	80
5.8 Full Width of the Predicted Agent Deposition Pattern for 100 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category F and a 3 m/s Wind Speed	80
5.9 Full Width of the Predicted Agent Deposition Pattern for 100,000 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category B and a 3 m/s Wind Speed	81

TABLES (Cont'd)

5.10 Full Width of the Predicted Agent Deposition Pattern for 100,000 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category D and a 3 m/s Wind Speed	81
5.11 Full Width of the Predicted Agent Deposition Pattern for 100,000 lb of HD Released as 10-um Droplets at a Height of 100 m into an Atmosphere with Stability Category F and a 3 m/s Wind Speed	82
6.1 Typical Key Words Used in Computerized Literature Searches	85
6.2 Estimated HD Vapor Capacity of the Cloud	87
6.3 Estimated VX Vapor Capacity of the Cloud	88
B. 1 Coefficients for Antoine's Equation from the D2PC Computer Code	101
B.2 Vapor Pressure as a Function of Temperature	102
B.3 Volatility as a Function of Temperature	102
D. 1 Summary of Parameter Values Used in the Parametric Model Study	109
D.2 Maximum Downwind Distance for Release of HD into an Atmosphere of Stability Category B	110
D.3 Maximum Downwind Distance for Release of HD into an Atmosphere of Stability Category D	110
D.4 Maximum Downwind Distance for Release of HD into an Atmosphere of Stability Category F	110
D.5 Maximum Downwind Distance for Release of VX into an Atmosphere of Stability Category B	111
D.6 Maximum Downwind Distance for Release of VX into an Atmosphere of Stability Category D	111
D.7 Maximum Downwind Distance for Release of VX into an Atmosphere of Stability Category F	111

FIGURES

1.1	Framework for Investigating the Potential for the Deposition of Chemical Agent Beyond Depot Boundaries	5
3.1	Location of the Eight Chemical Stockpile Storage Depots in the Continental United States	14
3.2	Schematic Diagram of a Typical Chemical Storage Depot	15
3.3	Map of Aberdeen Proving Ground and Vicinity	18
3.4	Map of Anniston Army Depot and Vicinity	22
3.5	Map of Blue Grass Army Depot and Vicinity	28
3.6	Map of Newport Army Ammunition Plant and Vicinity	33
3.7	Map of Pine Bluff Arsenal and Vicinity	37
3.8	Map of Pueblo Depot Activity and Vicinity	43
3.9	Map of Tooele Army Depot and Vicinity	48
3.10	Map of Umatilla Depot Activity and Vicinity	54
5.1	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Agent Types	73
5.2	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Masses Released	74
5.3	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Droplet Diameters	75
5.4	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Release Heights	76
5.5	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Atmospheric Stability Categories	77
5.6	Deposition Density as a Function of Downwind Distance as Predicted by GAPCAP for Various Wind Speeds	78
5.7	Schematic Representation of the Lateral and Downwind Extent of the Deposition Pattern Predicted by the GAPCAP Model	79

FIGURES (Cont'd)

C.1	Correspondence Between Gaussian and Top-Hat Profiles	105
C.2	Cloud Shape During a Release Event of Finite Duration	105
C.3	Cloud Shape Following a Release Event of Finite Duration	107
D. 1	Maximum Downwind Distances to Specific Deposition Levels for Releases of HD into an Atmosphere of Stability Category D	113