NATO STANDARD

AEP-72
Volume I

RECOMMENDED CHEMICAL, BIOLOGICAL AND TIC CHALLENGE LEVELS

Edition B Version 1
APRIL 2017

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED ENGINEERING PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

INTENTIONALLY BLANK

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

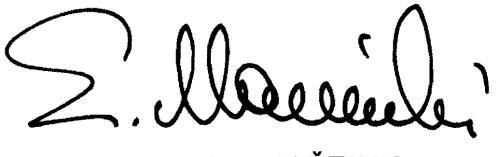
25 April 2017

1. The enclosed Allied Engineering Publication AEP-72, Volume I, Edition B, Version 1, RECOMMENDED CHEMICAL, BIOLOGICAL AND TIC CHALLENGE LEVELS, which has been approved by the nations in the NATO ARMY ARMAMENTS GROUP, is promulgated herewith. The recommendation of nations to use this publication is recorded in STANREC 4726.

2. AEP-72, Volume I, Edition B, Version 1, is effective upon receipt and and supersedes AEP-72, Edition A, Version 1, which should be destroyed in accordance with local procedures for the destruction of documents

3.

4. This publication shall be handled in accordance with C-M(2002)60.



Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

INTENTIONALLY BLANK

RESERVED FOR NATIONAL LETTER OF PROMULGATION

INTENTIONALLY BLANK

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Documents Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Documents Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

TABLE OF CONTENTS

INTENTIONALLY BLANK

1 AIM

The purpose of Volume I of this Allied Engineering Publication (AEP) is to recommend deposition and dosage levels of chemical agents, biological warfare agents and toxic industrial chemicals (TIC) to which protective equipment and procedures for NATO forces should be designed to allow unaffected operations. These challenge levels are intended to provide design guidelines and are not to be used for "risk assessment".

2 CHALLENGE LEVEL DEFINITION

Challenge level is defined as the chemical, biological and TIC concentration, dosages and contamination densities over time that can be expected in the field during realistic attacks, under the assumption that the attacker would make optimum use of the available weapons and weapon carriers and would divide them as well as possible over high/medium and low value targets.

3 AEP-72 STRUCTURE

Volume I of AEP-72 presents a NATO Unclassified Releasable to PFP Challenge level summary of the other AEP-72 volumes.

Volume II covers chemical agent challenge levels. Volume III covers TIC challenge levels. Volume IV covers biological warfare agent challenge levels.

4 AEP-72 APPLICATIONS AND LIMITATIONS

AEP-72 presents chemical, biological and TIC challenge levels summarized in and derived from technical reports created by the former NATO Challenge Sub-Group (CSG) and its successors based on studies done by the NATO CSG member nations. The technical reports listed in Chapter 9 contain more detailed and additional information, including descriptions of the hazard prediction models used and the assumptions behind the modelling conducted. The information presented here includes results considered most relevant to the implementation of techniques, tactics and procedures and equipment design. Most of the recommended challenge levels are in terms of dosage. In general, dosage challenge levels are most useful for design of protection equipment and medical treatments for acute effects. Some dosage challenge levels are presented for a series of time intervals, providing higher design fidelity. Deposition results are most useful for decontamination. Concentration time profiles are desirable for detection and medical/toxicological effects.

It is recognized that there are a number of limitations to the breadth of the studies behind this AEP. The chemical, TIC and biological sections of this volume I include more specific descriptions of the limitations, but some general comments are provided here.

- The vignettes considered are intended to provide a reasonable cross-section of the expected incident types ranging from force-on-force attacks to asymmetric or terrorist attacks. The set of vignettes is by no means comprehensive and

does not address all possible releases or environmental conditions, e.g. indoor releases, rendering safe operations and missile intercept actions.

- Military operations associated with support to emergency responders following a terrorist attack on civilians are not considered.
- The challenge levels address the time period over which acute effects are expected to occur, so information relevant to low level exposures following the initial, high challenge level period is not included. The current challenge levels worked out for protection may be of limited use to groups associated with sample collection, identification and monitoring, hazard management, emergency response, decontamination or medical treatment of chronic or threshold effects.
- Challenge levels due to contact transfer of chemical agents, TIC liquid or biological organisms to equipment and clothing are not considered.
- The off-gassing or other chemical fate of transferred liquid is not considered.
- Challenge levels are not interpreted in terms of human toxic effects.
- Deposition challenge levels are calculated for horizontal surfaces and thus have limited applicability for deposition on skin or clothing.

5 CHEMICAL AGENT CHALLENGE LEVELS

5.1 INTRODUCTION

Chemical agent challenge levels were first reported by the former Working Group of Experts (WGE1) in 1994 with the production of the document AC/225(Panel VII)D/312 Part 1 entitled “Report of Working Group of Experts on Chemical Challenge Levels, Part 1, Chemical Challenges to Individual and Collective Protection”. In 2000, the former CSG[1] was tasked by Land Group 7 to revisit the Chemical Agent Challenge levels. The CSG produced the September 2001 report[2] containing revised chemical agent challenge levels. In addition, this report provided a discussion of the implications of the challenge levels on protection requirements, and provides recommendations for consideration by the writers of Triptychs.

In 2003 the CSG was once more tasked to revisit the chemical agent challenge levels in light of evolving threats, including asymmetric attacks and toxic industrial chemicals (TIC). Furthermore, the CSG was also tasked to include a vulnerability analysis to evaluate if ‘NATO defined’ protection (as defined in the various NATO triptychs/AEPs) is adequate, given the challenges resulting from the various threat scenarios and the toxicology of the chemicals. The chemical agent challenge data presented in this AEP are taken from the latest CSG report submitted to the JCGCBRN in February 2006 and finalized and published in June 2010[3].

[1] Joint Capability Group on Chemical, Biological, Radiological and Nuclear (CBRN) Defence. Sub Group on the Chemical and Biological Challenge/Threat to NATO Forces. NATO/CNAD/NAAG/JCGCBRN/CSG
[2] AC/225(LG/7)D(2001)5
[3] AC/225(JCGBN-CSG)D(2010)0001

The CSG performed additional modelling and analysis to break the vapour challenge levels down by chemical agent and exposure time period to provide the NATO Physical Protection Sub-Group (PPSG) with time dependent challenge levels for selected vignettes.

5.2 METHODOLOGY

Calculations were performed using the Dutch RAP2004 model developed by TNO (version 17 June 2005). Supporting analysis has been performed with the US HPAC version 4.04 with Service Packs 1 and 3 and by the US VLSTRACK 3.1.2.

Calculations for the low intensity attacks within time intervals study were performed using the French ADMA software application developed by the DGA.

5.3 VIGNETTES AND CHEMICAL WEAPONS SYSTEMS

For the purposes of determining chemical challenges as the result of chemical attacks, it was necessary to establish descriptions of chemical attacks that might be experienced by deployed NATO forces and installations. The CSG decided to use the term 'vignettes'[4] for generic descriptions of such attacks.

Eight vignettes have been defined capturing both symmetric (force on force) and low intensity conflict (asymmetric) threats. The details and results for these studies are presented in AEP-72, Volume II.

5.4 CHEMICAL AGENT CHALLENGE LEVELS APPLICATIONS AND LIMITATIONS

The recommended chemical agent challenge levels are in terms of dosage and are most useful for designers of physical protective equipment and for medical treatment of acute effects. Volume II of this AEP also presents dosage challenge levels for the asymmetric attacks for a series of time intervals, thereby providing higher design fidelity. Chemical agent deposition results are most useful for decontamination.
Limitations for the chemical agent challenge levels in this AEP include:

- The vignettes considered are intended to provide a reasonable cross-section of the expected incident types ranging from force-on-force attacks to asymmetric or terrorist improvised device attacks. The set of vignettes includes a wide variety of release and environmental conditions to enable the probabilistic format used to present the deposition and dosage challenge levels, but the set of vignettes is by no means comprehensive.
- Challenge levels associated exclusively with secondary evaporation are not included.

[4] In the past the CSG called these scenarios, but in a military setting this term is often used/reserved for descriptions of a 'red-on-blue' campaigns/engagements of military opponents and this has caused some confusion. In contrast, the CSG vignettes are generic descriptions of a 'possible chemical incident' in such a campaign/engagement. A vignette therefore is more a 'snapshot incident' within a campaign.

- Deposition challenge levels represent the total deposited mass within the target area and do not address deposition levels as a function of time.
- Attacks within an urban environment are not considered.

A more detailed discussion on limitations can be found in AEP-72, Volume II.

5.5 RECOMMENDATIONS

Taking into account what the former CSG considered as the technical threat to NATO operations, the *essential* and *desired* challenge levels resulting from attacks with chemical weapons recommended for the design of CBRN defence equipment can be found in Table 5.1.

Table 5.1 Recommended essential and desired challenge levels for protection against chemical weapons.

Study	Dosage Vapour mg min m^{-3}		Deposition Liquid g m^{-2}	
	essential	desired	essential	desired
Symmetric attacks	**5 000**	**16 000**	**5.0**	**35**
Low intensity conflict	**700**	**1 400**	**4.0**	**8.0**

The *essential* deposition and dosage level is the challenge level that is not surpassed on 95% of the target area in an incident variation. This is regarded as a minimum acceptable level for defensive equipment. 5% of the target area experiences higher challenge levels than this value, and 95% of the target area experiences lower challenge levels.

The *desired* deposition and dosage level is the challenge level that is not surpassed on 99% of the target area in an incident variation. 1% of the target area experiences higher challenge levels than this value, and 99% of the target area experiences lower challenge levels.

Further details can be found in AEP-72, Edition A, Version 2, Volume II.

6 TOXIC INDUSTRIAL CHEMICALS (TIC) CHALLENGE LEVELS

6.1 INTRODUCTION

The deliberate or accidental release of Toxic Industrial Chemicals (TIC) against NATO forces could result in both large hazard areas and high operational risks. Future TIC operating environments are both variable and unpredictable when factoring TIC release complexities, various storage and transport sizes and diverse storage conditions. A spectrum of scenarios and likely release sizes are possible. The former CSG assessed functional information pertaining to TIC hazards and risks and operational challenge levels to provide TIC challenge level data and guidance to

support TIC defence planning, procedures and materiel standards development for NATO Forces.

The results of eight interrelated TIC studies were reviewed in AEP-72 Volume III. For more details, please refer to AEP-72 Volume III and "Revised Report on Toxic Industrial Chemical (TIC) Challenge Levels" and its associated appendices.[5]

6.2 METHODOLOGY

Based on the comparison between the eight studies mentioned in Chapter 6, section 6.1, a list of prioritised TIC was derived, which can be found in Table 6.1. Eighteen of these TIC, as indicated in the table, were modelled. To obtain recommended challenge levels, the selected time period was the first 60 minutes following the incident, the selected downwind distance was 1 km from the point of release, and the selected eighteen TIC were categorised based upon volatility.

The respective prioritization and selection rationales, as well as the detailed challenge level data, are provided in AEP-72 Volume III.

Table 6.1 CSG List of Priority TIC, with modelling status indicated.

Chemical	CAS #	UN Number	Modelling status
Acrolein	107-02-8	1092	X
Ammonia	7664-41-7	1005	X
Chlorine	7782-50-5	1017	X
Cyanogen chloride	506-77-4	1589	X
Formaldehyde	50-00-0	2209	X
Hydrogen bromide	10035-10-6	1048	X
Hydrogen chloride	7647-01-0	1050	X
Hydrogen cyanide	74-90-8	1051	X
Hydrogen fluoride	7664-39-3	1052	X
Hydrogen sulfide	7783-06-4	1053	X
Mercury	7439-97-6	2809	X
Methylbromide	74-83-9	1062	X
Nitric acid	7697-37-2	2031	X
Nitrogen dioxide	10102-44-0	1067	X
Octamethyl pyrophosphoramide	152-16-9	3018	X
Phosgene	75-44-5	1076	X
Sulfur dioxide	7446-09-5	1079	X
Sulfuric acid	7664-93-9	1830	X
Acrylonitrile	107-13-1	1093	

[5] AC/225(JCGCBRN-CSG)D(2011)0001-REV1

Chemical	CAS #	UN Number	Modelling status
Allyl alcohol	107-18-6	1098	
Arsine	7784-42-1	2188	
Benzene	71-43-2	1114	
Boron trifluoride	7637-07-2	1008	
Carbon monoxide	630-08-0	1016	
Diborane	19287-45-7	1911	
Dimethylamine	124-40-3	1032	
Ethylene oxide	75-21-8	1040	
Fluorine	7782-41-4	1045	
Hydrazine	302-01-2	2029	
Hydrogen selenide	7783-07-5	2202	
Methyl hydrazine	60-34-4	1244	
Methyl isocyanate	624-83-9	2480	
Methylamine	74-89-5	1061	
Parathion	56-38-2	3018	
Phosphoric acid	7664-38-2	1805	
Phosphorous trichloride	7719-12-2	1202	
Phosphoryl trichloride	10025-87-3	1810	
Potassium cyanide	151-50-8	1680	
Propylene oxide	75-56-9	1280	
Sodium cyanide	143-33-9	1689	
Sodium hydroxide	1310-73-2	1823	
Sulfur trioxide	7446-11-9	1829	

6.3 TIC CHALLENGE LEVELS APPLICATIONS AND LIMITATIONS

The recommended TIC challenge levels are in terms of dosage and are most useful for designers of physical protective equipment and for medical treatment of acute effects. For some of the TIC vignettes, Volume III of this AEP also presents dosage challenge levels for a series of time intervals, concentration time profiles, and areas for a range of concentration levels, thereby providing higher design fidelity. Liquid pool areas and durations are provided in the original technical reports and are most useful for decontamination. Concentration time profiles are most useful for detection.

Limitations for the TIC challenge levels in this AEP include:

- The vignettes considered are intended to provide a reasonable cross-section of the expected incident types for the TIC evaluated to be of most concern. The vignettes also consider rural, suburban, and urban environments. Although some TIC have been employed in state-program chemical munitions, the TIC incidents addressed by the studies are all considered to represent terrorist

attacks. The set of vignettes includes a very limited set of release and environmental conditions intended to be favourable to generation of large hazard areas; the set of vignettes is by no means comprehensive.

- Challenge levels are mostly limited to 60 minutes after the attack to reflect human responses of either acute effects or evacuation, so long term exposure or exposure to emergency responders is not considered. In some cases, liquid pool evaporation can extend the challenge over many hours.
- Although the technical reports address liquid pool and vapour cloud durations, no characterization of residual contamination is included.

6.4 RECOMMENDATIONS

The time period of interest is the first 60 min following the incident. The resulting challenge levels are essentially a function of TIC vapour pressure. The TIC stored as pressurized liquids (i.e., boiling temperature below 0 °C) lead to the highest dosage values, followed by the TIC that have boiling temperatures near ambient (i.e., boiling temperature from 0 °C to 30 °C), and then the low volatility liquids (i.e., boiling temperature above 30 °C); this last group includes the industrial acids and bases, where higher vapour pressures (e.g., acrolein) typically lead to the highest challenge levels.

The results for the TIC challenge levels are presented for large releases of pressurized liquids, high and low volatile liquids and small releases of pressurized or volatile liquids. Given the high challenge levels for chlorine releases from a giant storage tank, chlorine is mentioned separately. Small releases of the low volatility chemicals will not lead to a significant challenge level.

Taking into account what the former CSG considered as the technical threat to NATO operations, the challenge levels resulting from releases of TIC recommended for the design of CBRN defence equipment can be found in Table 6.2.

Table 6.2 Recommended essential challenge levels for protection against single TIC attacks/accidental releases.*

TIC	Storage tank/release size	Dosage Vapour mg min m^{-3}
Chlorine	Giant storage tank	**300 000**
Pressurized liquid	Storage tank, railcar or tanker truck	**50 000**
Volatile liquids	Large release	**10 000**
Low volatility liquids	Large release	**2 000**
Pressurized or volatile liquids	Small release	**500**

*Only four chemicals had high dosage values at the 3 km distance, so only a single set of challenge levels is presented here, reflecting the results at the 1 km distance.

Further details can be found in AEP-72, Edition A, Version 2, Volume III.

7 BIOLOGICAL WARFARE AGENT CHALLENGE LEVELS

7.1 INTRODUCTION

In and before the 1990's the Biological agent challenge levels were assumed to be identical to the chemical challenge levels. In 2000 the former CSG was tasked to evaluate the biological threat and suggest biological challenge levels. The CSG report from that study was published in October 2000.[6]

In 2006 the CSG was again tasked to evaluate the biological challenge. The results of the 2006 biological challenge study were published in 2009.[7] The CSG have also conducted a study on post-attack biological warfare hazards.[8] That study defined hazards from biological agent deposition, organism persistence on surfaces, infection through skin contact, and reaerosolisation. Results from that study for deposition and reaerosolisation challenge levels are also included in this document.

In 2013, the CSG was disbanded. The Joint Chemical Biological Radiological and Nuclear Defence Capability Development Group (JCBRND-CDG) created the Chemical and Biological Challenge Levels Team of Experts (CBCL TOE) and tasked it to continue the work of the CSG by finalising AEP-72 Volume IV.

7.2 METHODOLOGY

The analysis in AC/225(JCGCBRN-CSG)D(2009)0001-REV1 was performed using the Risk Assessment Package (RAP) model, which is part of the Chemical and Biological Incident Simulation (CABIS) model. A comparison between RAP and HPAC was performed using the same input parameters. The results are presented in AC/225(JCGCBRN-CSG)D(2009)0001-REV1 and compare closely between the two models and also with the results reported by AC/225(LG/7)D/57 for matching vignettes.

Seven vignettes from AC/225(JCGCBRN-CSG)D(2009)0001-REV1 and AC/225(LG/7)D/57 capturing both force on force and asymmetric threats have been recalculated by TNO in 2013 with CABIS, using the RAP model to obtain and tabulate challenge levels and to provide dosage vs. distance profiles.

The post-attack hazard analysis study conducted in 2002[8] focused on biological warfare agent reaerosolisation. The vignettes were simulated using three models, RAP 2000, HPAC 3.2.1 and VLSTRACK.

The details and results for these studies are presented in AEP-72, Volume IV.

[6] AC/225(LG/7)D/57
[7] AC/225(JCGCBRN-CSG)D(2009)0001-REV1
[8] AC/225(LG/7)D(2002)9

7.3 BIOLOGICAL WARFARE AGENT CHALLENGE LEVEL APPLICATIONS AND LIMITATIONS

The recommended biological warfare agent (BWA) challenge levels are in terms of dosage at operationally relevant downwind distances and are most useful for designers of physical protective equipment and for medical care. Information on biological agent deposition and reaerosolisation is also useful for these same applications. Deposition values are useful for designers of surface contamination detection and identification equipment and methods, as well as decontamination equipment, solutions, and methods.

Limitations for the biological challenge levels in this AEP include:

- The vignettes considered are intended to provide a reasonable cross-section of the expected incident types for the biological warfare agents of most concern; the set of vignettes is by no means comprehensive.
- Challenge levels are integrated over the duration of the hazard from the release time until the plume no longer contributes to the exposure to organisms.
- The current challenge levels provided for protection may be of limited use to other groups, including those associated with aerosol sample collection, identification and monitoring, emergency response or medical treatment of chronic or threshold effects.
- Five BWAs are addressed, which cover a wide range of infectivity and environmental viability but do not consider variation in other properties. The agents were selected to provide guidance for equipment design.
- The vignettes used for post-attack hazard analysis provide reliable estimates of particle deposition and reasonable estimates of the longevity of deposited particles.

A more detailed discussion on limitations can be found in AEP-72, Volume IV.

7.4 RECOMMENDATIONS

Taking into account what the former CSG and the former CBCL TOE considered as the technical threat to NATO operations, the *essential* and *desired* challenge levels resulting from attacks with biological weapons recommended for the design of CBRN defence equipment can be found in Table 7.1 and Table 7.2.

Table 7.1 Recommended *essential* and *desired* aerosol challenge levels for protection against biological weapons

Attack	Dosage mg min m^{-3}	
	essential	desired
Force on force attack	**2**	**30**
Asymmetric attack	**0.004**	**0.2**

Essential challenge levels represent dosage at 10 km downwind distance, and *desired* challenge levels represent the dosage at 2 km downwind distance.

Table 7.2 Recommended *essential* and *desired* deposition challenge levels for protection against biological weapons

Attack	Deposition mg m^{-2}	
	essential	desired
On target attack	**1**	**50**
Off target attack	**0.004**	**0.03**

Essential and *desired* challenge levels for on target attacks are defined as above for chemical agents. For off target attacks, *Essential* challenge levels represent dosage at 20 km downwind distance, and *desired* challenge levels represent the dosage at 2 km downwind distance.

Further details can be found in AEP-72, Edition A, Version 1, Volume IV.

8 CONCLUSION

Based on the CSG and CBCL TOE technical threat perception (agents, delivery systems and doctrine), the CBCL TOE recommends the use of the chemical agent challenge levels in Table 5.1, the toxic industrial chemicals challenge levels in Table 6.2 and the biological warfare agent challenge levels in Table 7.1 and Table 7.2 in order to provide NATO operations the ability to develop CBRN equipment and procedures.

9 REFERENCES

Report of the Challenge Sub-Group on Chemical Agent Challenge Levels.
AC/225(LG/7)D(2001)5, 27 November 2001. NATO Confidential.

Final Report on Chemical Agent Challenge Levels.
AC/225(JCGCBRN-CSG)D(2010)0001, 18 June 2010. NATO Restricted.

Challenge Study Estimates for NATO Lightweight Suit Requirements.
AC/225(JCGCBRN)D(2012)0001, 2 April 2012. NATO Unclassified.

Revised Report on Toxic Industrial Chemical (TIC) Challenge Levels.
AC/225(JCGCBRN-CSG)D(2011)0001-REV1, 5 January 2012. NATO Restricted.

Challenge Level Recommendations for Toxic Industrial Chemicals (TIC).
AC/225(JCGCBRN)D(2012)0002 (PFP), 2 April 2012. NATO Unclassified Releasable to PFP.

Report of the Challenge Sub-Group on Biological Agent Challenge Levels.
AC/225(LG/7)D/57, 6 October 2000. NATO Secret.

Guide on Post-Attack Biological Warfare Hazards.
AC/225(LG/7)D(2002)9, 14 October 2002. NATO Restricted, Releasable to EU.

Final Report on Biological Challenge Levels.
AC/225(JCGCBRN-CSG)D(2009)0001-REV1, 30 November 2009. NATO Secret.

10 GLOSSARY

ADMA	Atmospheric Dispersion Modelling Automation
BWA	Biological Warfare Agent
CABIS	Chemical and Biological Incident Simulation
CBCL TOE	Chemical and Biological Challenge Levels Team of Experts
CSG	Challenge Sub Group
DGA	Direction Génerale De L'Armement
DNSA	Director NATO Standardization Agency
HPAC	Hazard Prediction and Assessment Capability
IDA	Institute for Defense Analyses
JCBRND-CDG	Joint Chemical Biological Radiological and Nuclear Defence Capability Development Group
JCGCBRN Defence	Joint Capability Group on Chemical, Biological, Radiological and Nuclear (CBRN) Defence
LG	Land Group
MFR	Memorandum for Record
NATO	North Atlantic Treaty Organization
NSO	NATO Standardization Office
NSWCDD	Naval Surface Warfare Center Dahlgren Division
OHA	Operational Hazard Analysis
OMPA	Octamethyl pyrophosphoramide
ORA	Operational Risk Assessment
PHAST	Process Hazard Analysis Software Tools
PPSG	Physical Protection Sub Group
RAP	Risk Assessment Package
STANREC	Standardization Recommendation
TIC	Toxic Industrial Chemical
TIM	Toxic Industrial Material
TNO	Netherlands Organisation for Applied Scientific Research
TTTF	TIC/TIM Task Force
VLSTRACK	Vapor, Liquid, Solid Tracking
WGE	Working Group of Experts

INTENTIONALLY BLANK

AEP-72(B)(1)
Volume I